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Bank Bail-outs, International Linkages and Cooperation*

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Abstract

Financial institutions are increasingly linked internationally and engaged in cross-border operations. As a result, financial crises and potential bail-outs by governments have important international implications. Extending Allen and Gale (2000) we provide a model of international contagion allowing for bank bail-outs financed by distortionary taxes. In the sequential game between governments, there are inefficiencies due to spillovers, free-riding and limited burden-sharing. When countries are of equal size, an increase in cross-border deposit holdings improves, in general, the non-cooperative outcome. For efficient crisis management, ex-ante fiscal burden sharing is essential as ex-post contracts between governments do not achieve the same global welfare.

Keywords: bail-out, contagion, financial crisis, international institutional arrangements

JEL-Codes: F36, F42, G01, G28

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1 Introduction

With globalization, banks have become more and more linked internationally and engaged in cross-border operations. As a result, banking crises today have international dimensions which make bail-out decisions less of a domestic and more of an international issue, with governments in different countries responding and consumers in different countries being affected. In this paper we present a theoretical model of international contagion, where governments decide domestically upon ex-post intervention and explore inefficiencies from unilateral decision-making. We analyze how different forms of cooperation can improve upon the non-cooperative outcome.

Banking crises are a frequent phenomenon. Caprio and Klingebiel (2003) compiled a data set with information on 117 systemic banking crises that have occurred in 93 countries since the late 1970s. In most countries, banking crises led to intervention by national governments, the fiscal costs of which have been considerable. Honohan and Klingebiel (2000) study a sample of 40 countries and find that, in order to restore the financial system, governments spent on average 12.8 percent of national GDP. Often, this implies rising government debt. Reinhart and Rogoff (2009) investigate the aftermath of financial crisis and find that the real value of government debt tends to increase sharply. While the collapse in tax revenues resulting from contractions of real output is the major reason for this, bail-out and recapitalization costs can be an important factor, too. During the recent financial crisis, governments all over the world have responded with significant financial support. In a report, the IMF provides an overview of taken measures and related costs. Upfront commitments for financing pledged support operations are estimated at 5.7 % of GDP for the advanced G-20 as of August 2009. Pledged capital injections alone amount to 2.2% of G-20 GDP. (see Tables 3 and Annex Tables 3 and 4 of IMF (2009)).

The recent global financial crisis, which emanated from the United States, showed how crisis can spread from one country to another. Degryse and Penas (2009) analyze cross-border contagion risk for the period from 1996 to 2006 using data on cross-border exposure of 17 countries. They find that the speed of propagation of contagion has increased over the past years and that a shock which affects the liabilities of one country may undermine the stability of the global financial system. In the face of contagion risk due to increasing cross-border exposures and high economic costs associated with banking crises, banks in distress become an international issue. Claessens (2009) investigates financial nationalism in the context of the current financial crisis. He gives evidence for international effects of unilateral government intervention. Guarantees

on deposits and other liabilities issued by individual countries had beggar-thy-neighbor effects. Countries also started to ring-fence assets in their jurisdictions when cross-border entities showed signs of failing, like the German government that froze Lehman assets in 2008. Other examples for conflicting international interests in the context of financial institutions in distress are the AIG bail-out by the U.S. Federal Reserve in 2008, which benefited several non-U.S. financial institutions, as well as the bankruptcy case of Icesave in 2009 concerning Dutch and British depositors.

Such conflicting international interests give rise to potential gains from cooperation between governments. The initiative of the European Union toward a new financial architecture, a response to the current financial crisis, is, amongst other things, meant to foster cooperation in crisis management. It has been argued that the resolution of distressed cross-border banks within the EU is not handled efficiently. Crisis management is limited to the national level or ad-hoc cross-border solutions (see De Larosiere Report (2009)). Correspondingly, little cooperation of governments was observed during the current crisis. An exception are Belgium, the Netherlands and Luxembourg, with some involvement of France, who cooperated to a certain extent in order to resolve Dexia and Fortis (see Claessens (2009)). The first plans of the EU Commission to endow a European regulator with the right to enjoin individual governments to bail out a national bank at their own expense was dismissed. However, due to the perceived need for EU-wide coordination, the European Systemic Risk Board, a new EU institution, has been given the task to issue policy recommendations on how to deal with distressed banks.

In the following we study a model of international contagion where banks are linked through interbank deposits. We analyze a sequential game between two governments facing a potentially contagious banking crisis. Governments can prevent bankruptcy by doing a bail-out financed by distortionary taxes, which has spillover effects on the other country. We show that inefficiencies in the bail-out decision of governments arise when there is no international cooperation. We introduce private cross-country deposits to study their effects on efficiency in the non-cooperative outcome. In a next step, we focus on fiscal burden sharing, which can further improve efficiency. Finally, we model Nash bargaining between governments and consider how a central authority with mandating and/or fiscal power or contracts impact global and national welfare.

Contagion model Building upon Allen and Gale (2000), we model cross-border financial linkages in form of interbank deposits. Interbank deposits allow for risk sharing of idiosyncratic

liquidity needs, but induce systemic risk. Crisis spreads from the one bank to the other bank in the system when the former goes bankrupt due to unexpected liquidity needs and interbank deposits cannot be repaid fully. Facing a bankrupt bank, governments can decide not to take any action. Then, the bankrupt bank is liquidated. Alternatively, the government may bail out its bank financed by distortionary taxes. This action directly affects depositors of the bank that is saved and domestic households that are taxed. Moreover, it impacts the foreign bank and its depositors, either because contagion is avoided (spillover effect on the *affected country*) or because its liquidation value is raised (spillover effect on the *crisis country*).

We study inefficiencies in government intervention when there is no international authority. In the sequential bail-out game the country where the crisis arises moves first, the other one follows. We identify three distinct sources of inefficiencies. First, externalities arise from the fact that governments maximize national welfare, but do not take the spillover effects into account which impact the welfare of the other country. In this context, we find a second source of inefficiency, a free-riding problem that arises through the sequential nature of our model. The crisis country may not bail out its domestic bank because it knows that then the affected country will do a bail-out. This, in turn, benefits the crisis country through the positive spillover in form of increased returns on interbank deposits. In this way, as the first mover, it can free ride on the bail-out carried out by the affected country. The larger the interbank linkages, the larger the spillovers and the bigger the incentives to free-ride. A third inefficiency arises due to no burden-sharing, i.e. the inability, in the non-cooperative game, to share the costs of a bail-out that arise in one country between the two governments. Furthermore, we analyze the effects of cross-country deposits and asymmetric country sizes on government intervention. Due to private cross-country deposits, governments take spillover effects in their bail-out decision into account. Whether cross-country deposits tend to increase or decrease efficiency depends on the extent of cross-country deposits and potential asymmetries in country sizes. We find that, if country sizes are equal, cross-country deposits tend to reduce inefficiencies.

We study three different forms of cooperation: a central authority with mandating power and/or fiscal power, and contracts. Our main findings are the following: A central authority with mandating and fiscal power achieves the best ex-post outcome trading off income inequality with distortions from taxation. At an optimum, burden sharing is such that the affected country always contributes more than the crisis country. This can, but does not need to imply a Pareto improvement compared to the non-cooperative solution. A central authority with

mandating power alone cannot induce a Pareto improvement compared to the non-cooperative solution, whereas contracts imply this by their very nature. The two regimes alleviate different inefficiencies. A clear ranking between them in terms of efficiency is therefore not possible. In general, mandating power alone or ex-post contracts do not achieve as high a welfare level as an authority with mandating and fiscal power.

Related literature There are several approaches to model contagion. One is to model contagion as driven by information. Bad news about one bank imply, due to a correlation in the value of assets, bad news for another institution (see Acharya and Yorulmazer (2008) and Chen (1999)). A different mechanism is proposed in Diamond and Rajan (2005) who show that contagion can be an equilibrium phenomenon because bankruptcy of one bank may reduce the available aggregate liquidity, which then causes bankruptcy of potentially all banks in the system. The third approach, which we follow in this paper, explains contagion by the fact that banks are connected through their balance sheets. In Allen and Gale (2000) systemic risk arises because banks are linked through interbank deposits that insure banks against idiosyncratic liquidity risk. Default of one bank reduces the value of assets in other banks, the ultimate consequence of which can be the failure of the entire banking system. Dasgupta (2004) applies the theory of global games, developed by Carlsson and van Damme (1993) and introduced to this setting by Morris and Shin (2003), to a similar setup. Depositors receive private, but correlated signals about the fundamentals of the bank they deposited in. Depending on the signal, a bank run occurs and crisis spreads along the channels of interbank deposits.

There is a large literature on optimal government intervention at the national level and the role for a Lender of Last Resort (LLR). The classic doctrine of Bagehot (1873) that central banks should lend to illiquid, but solvent banks has been studied extensively (see i.e. Rochet and Vives (2004), Freixas, Parigi, and Rochet (2000) and Freixas and Parigi (2008) for a summary of the literature on the LLR). Castiglionesi (2007) investigates the role of a central bank in the framework of Allen and Gale (2000) where it can prevent financial contagion by setting appropriate reserve requirements. Bail-outs have also been studied by Diamond and Rajan (2002). In their paper, bail-outs increase the aggregate liquidity available, which can lead to ambiguous effects on the stability of the banking system. In Gorton and Huang (2004), private hoarding of liquidity is socially costly. A government can reduce this hoarding by subsidizing distressed banks as it can issue government securities backed by future tax revenues. Goodhart

and Huang (2005) consider the trade-off between liquidity support and moral hazard costs which central banks face and rationalize the argument for so-called 'constructive ambiguity'. Cordella and Yeyati (2003) show that bail-outs can instead have risk-reducing effects. The optimal institutional arrangement for the LLR function is the focus of some further studies e.g. Kahn and Santos (2005) and Repullo (2000).

Some recent contributions put banking theory in an international perspective. One focus of the literature on regulation is on analyzing the scope for international cooperation among bank regulators, i.e. on understanding the interactions between internationally operating banks, which are to be regulated, and national regulatory incentives. Holthausen and Roende (2005) study multinational banks and optimal closure policies, where each authority maximizes national welfare. Asymmetries of operating banks and of regulators' preferences across countries lead to suboptimal closure decisions in a 'cheap talk' game. Acharya (2003) considers the international standardization of ex-ante capital adequacy ratios and ex-post closure policies in a framework where domestic banks compete internationally. In his model, competition among banks leads to inefficient closure policies and finally increased risk in the banking system. Dell'Ariccia and Marquez (2006) look at the scope for centralized regulation when competing banks are heterogeneous across countries. Again, asymmetries lead to suboptimally low standards due to a trade-off between flexibility in policy design and increased stability of the banking system.

There is a policy debate on regulation and the LLR function in the context of a globalizing banking sector, especially within the European Union. Vives (2001) argues in favor of a bigger role for the European Central Bank in crisis management and more centralized supervisory arrangements. Teixeira and Schinasi (2006) raise the issue of cross-border externalities and the need for a centralized LLR for the EU Single Market. Pauly (2008) considers crisis management in Europe and makes the case for financial burden sharing rules among national governments. Claessens (2009) reviews government interventions taken during the current financial crisis with respect to competition policy and points at the need for international coordination.

While there is considerable theoretical work on international issues related to regulation and supervision, there are only few papers that study cooperation problems arising in an international banking crisis. Agur (2009) treats the question of the optimal institutional structure for a LLR in an international framework where depositors have imperfect information about the solvency of banks and government intervention has a signaling effect. While national governments do not internalize the contagion effect, a central authority has limited signaling power. Therefore,

the maximum welfare is achieved by central coordination rather than pure centralization of the bail-out decision. Freixas (2003) discusses externalities from bail-outs in a multi-country setting. In a standard public goods model, he analyzes cooperation mechanisms which implement first-best bail-outs. Goodhart and Schoenmaker (2009) extend this model and consider ex-ante fiscal burden sharing rules in order to induce optimal cooperation. Our model goes beyond the pure public goods problem of bank bail-outs that the latter two papers study and the framework of Agur (2009), as we explicitly model international interbank linkages and bail-out incentives in a contagion framework based on Allen and Gale (2000).

The remainder of this paper is structured as follows. Section 2 introduces the model. Section 3 discusses centralized and decentralized decision making and their efficiency properties. Section 4 extends the model by allowing for private cross-country deposits. Section 5 discusses fiscal burden sharing. Section 6 considers contracts. Section 7 compares different forms of cooperation with respect to efficiency and Pareto improvements. Section 8 studies ring-fencing. Section 9 concludes.

2 The model

Our model builds on Allen and Gale (2000). We use their basic framework to model interbank linkages and contagion. We extend the analysis to an international setting with two countries and allow for government interventions in case of bankruptcy after uncertainty about liquidity needs has been resolved. Moreover, we introduce a production sector operating at date $t = 1$, employing labor whose income can be taxed by the government in order to finance interventions.

2.1 Setup

There are three time periods indexed by $t = 0, 1, 2$ and a continuum of ex-ante identical agents of measure one. Each agent is endowed with one unit of a single consumption good at date $t = 0$. It serves as numéraire and can be invested in two different assets, a short asset and a long asset. The short asset represents a storage technology. For each unit invested at date t , it pays out one unit at date $t + 1$. The investment in the long asset can only take place at date $t = 0$, but gives a higher pay-off $R > 1$ at date $t = 2$. The long asset can be liquidated in period $t = 1$, but early liquidation is costly. For one unit invested at date $t = 0$, only $r < 1$ units can be

recovered. At date $t = 1$, each agent decides on its supply of labor to the perfectly competitive production sector. Each unit of labor produces 1 unit of the consumption good. Consumers have Diamond-Dybvig preferences. With probability λ , an agent only values consumption at date $t = 1$ (early type), while with probability $1 - \lambda$ it is of the late type and values consumption only at date $t = 2$. Individual preferences are given by:

$$U(c_1, c_2) = \begin{cases} u(c_1) & \text{with probability } \lambda \\ u(c_2) & \text{with probability } 1 - \lambda, \end{cases} \quad (1)$$

where u is assumed to be twice continuously differentiable, increasing and strictly concave. Consumption of an agent of type i c_i , is composed of three different elements: the return from the investment d_i made at date $t = 0$, labor income n , which depends on the labor supplied at date $t = 1$, and disutility of work expressed in consumption terms.¹ That is:

$$c_i = d_i + \eta \left(n - \frac{n^2}{\kappa} - \frac{\kappa}{4} \right). \quad (2)$$

Disutility of work is quadratic, with shape parameters κ and η . Due to our assumptions on the utility function, the labor supply decision of the agent is independent of its type and we can drop the subscript i .² The first order condition for labor of both types of individuals is:

$$\frac{du(c_i)}{dn} = u'(c_i)\eta \left(1 - \frac{2n}{\kappa} \right) = 0. \quad (3)$$

Therefore, in an optimum each agent supplies $n = \kappa/2$ units of labor. With the last term of Equation 2, we normalize the utility contribution of labor for the optimal labor supply to 0, which is convenient for our subsequent analysis.³

By the law of large numbers, the probability λ of being an early consumer, is also the fraction of early consumers in the economy. We assume that the population is divided into two groups of consumers, each of mass one. Within each group, the fraction of early consumers is stochastic. Across groups it is perfectly negatively correlated. There are two possible states of nature S_1

¹Our setup is similar to Cooper, Kempf, and Peled (2008).

²Late consumers, who only consume at date $t = 2$, store their labor income from date 1 to date 2. The disutility of labor, although conceptually arising at date $t = 1$, unfolds only at $t = 2$.

³Due to the normalization, the date-0 investment decision of the bank is not impacted by the level of the expected labor income and the bank's optimization problem that we consider later can be formulated as is standard in the literature.

and S_2 , which are summarized in Table 1, where λ_H denotes a high fraction of early consumers and $0 < \lambda_L < \lambda_H < 1$. Both states occur with equal probability. Groups of consumers are thus identical in expectation and aggregate demand for liquidity is the same in both states.

Table 1: Liquidity shocks

	Group A	Group B	Probability
State S_1	λ_h	λ_l	0.5
State S_2	λ_l	λ_h	0.5

2.2 Optimal risk sharing and the first-best allocation

To start with, we analyze the first-best allocation given the two available investment technologies. As there is no aggregate uncertainty, the optimal allocation implies perfect risk-sharing and allocations are independent of the two states. In order to find the first-best solution, we consider a social planner that has perfect information, hence knows the type of each consumer. The planner chooses investment at date $t = 0$ so as to maximize overall expected utility treating all consumers alike. The maximization problem includes three feasibility constraints and is as follows:

$$\begin{aligned} \max_{\{d_1, d_2\}} \quad & \bar{\lambda}u(c_1(d_1)) + (1 - \bar{\lambda})u(c_2(d_2)) & (4) \\ \text{s.t.} \quad & x + y \leq 1, \\ & \bar{\lambda}d_1 \leq y, \\ & (1 - \bar{\lambda})d_2 \leq Rx, \end{aligned}$$

where x and y are the per capita amounts invested in the long and the short asset, respectively. The three constraints represent the resource constraints at date $t = 0$, $t = 1$ and $t = 2$. The social planner anticipates the optimal labor supply by the agents. Substituting $n = \kappa/2$ yields the standard objective function, which is independent of labor income: $\bar{\lambda}u(d_1) + (1 - \bar{\lambda})u(d_2)$. The unique solution to the problem is characterized by the condition:

$$u'(\bar{d}_1) = Ru'(\bar{d}_2), \quad (5)$$

where \bar{d}_1 and \bar{d}_2 denote the consumption levels that early and late consumers receive.

As aggregate consumption at dates 1 and 2 is constant and liquidation of the long asset is costly, it is optimal to provide date-1 consumption by investing in the short asset and date-2 consumption by investing in the long asset. Thus, at the optimum, all constraints bind, and $\bar{d}_1 = y/\bar{\lambda}$ as well as $\bar{d}_2 = R(1 - y)/(1 - \bar{\lambda})$.

2.3 Decentralization and interbank deposits

In this section, we introduce a banking sector and show that the first-best allocation from above can be decentralized as an equilibrium with competitive banks. First, we describe the decentralized setting and define the equilibrium. Second, we discuss a specific deposit and interbank deposit contract and derive the corresponding equilibrium. Third, we show that the resulting allocation coincides with the first-best and prove equilibrium existence.

Assume that only banks can invest in the long asset. Therefore, they have two advantages: They can invest in both assets and, by pooling endowments, provide insurance against liquidity risk. The banking sector is perfectly competitive. This implies that, in order to attract funds, banks have to offer a contract that maximizes the expected utility of its depositors. We consider the following deposit contract D that is not contingent on the state of nature. A depositor can choose to withdraw at date $t = 1$ or at date $t = 2$. Per unit deposited, the contract specifies a repayment d_1 to depositors that withdraw at date $t = 1$. A late withdrawer receives a pro rata share of the bank assets remaining at date $t = 2$, which is denoted by d_2 . If the bank cannot serve all withdrawals at date $t = 1$, it is bankrupt and all depositors receive the same pro rata repayment. As there is no sequential service constraint, no expectation driven bank runs occur.⁴

We assume that each bank faces uncertainty about the fraction of early and late depositors as described in Table 1. Thus Group A corresponds to the depositors of Bank A and Group B to depositors of Bank B. This uncertainty introduces an incentive for banks to sign contracts with each other in order to insure against liquidity risk. Interbank deposit contracts have the same specification as the deposit contracts between consumers and banks. Repayments per unit of deposit are contingent on the date of withdrawal (d_1^I, d_2^I), but independent of the state. If the counterpart bank goes bankrupt, a bank receives a pro rata share of the counterpart's liquidation

⁴Note that our model does not feature multiple equilibria as e.g. in Diamond and Dybvig (1983), Cooper and Ross (1998), Ennis and Keister (2006) and Ennis and Keister (2009). Therefore, government intervention in our model is not driven by an equilibrium selection motive, but by a liquidity shortage.

value and thus incurs a loss on the interbank deposits. The amount of interbank deposits each bank makes is denoted by z .

The timing is as follows. At $t = 0$, consumers sign deposit contracts with the banks and deposit their endowments. Banks sign interbank deposit contracts and each deposit amount z . Moreover, banks invest in the long and the short asset. At date $t = 1$ uncertainty resolves and consumers learn privately about their types. At that stage, consumers can decide to withdraw their claims or wait until next period. Early consumers withdraw always, as they only have utility from consumption at date $t = 1$. Late consumers decide whether to withdraw at date $t = 1$ and store the good or to withdraw at date $t = 2$, depending on payoffs d_1 and d_2 . Banks do the same and decide whether to withdraw the claims $d_1^I z$ that they have at date $t = 1$. Define a withdrawal strategy for each bank w^I and late consumers w^L contingent on the state:

$$\begin{aligned} w^I(d, \lambda) &: \{d_1^I, d_2^I\} \times \{\lambda\} \rightarrow \{0, 1\}, \\ w^L(d) &: \{d_1, d_2\} \rightarrow \{0, 1\}, \end{aligned}$$

where 1 stands for withdrawal at date $t = 1$ and 0 for withdrawal only at date $t = 2$. Consumers and banks know the state that occurred and the fraction of early depositors in each bank.

An equilibrium is characterized by a deposit and an interbank deposit contract, and withdrawal strategies of banks and late consumers.

Definition 1 *An equilibrium is a deposit contract $\{D = (d_1, d_2)\}$, an interbank deposit contract $\{D^I = (d_1^I, d_2^I)\}$, an amount of interbank deposits $\{z\}$, a withdrawal strategy of banks $\{w^I(d, \lambda) : \{d_1, d_2\} \times \{\lambda\} \rightarrow \{0, 1\}\}$, a withdrawal strategy of late consumers $\{w^L(d) : \{d_1, d_2\} \rightarrow \{0, 1\}\}$ such that*

- (i) *the deposit contract D maximizes expected depositor utility given $\{D^I, z\}$,*
- (ii) *there does not exist another interbank deposit contract and amount of interbank deposits $\{D^I, z'\}$ that imply a higher expected utility for depositors,*
- (iii) *given $\{D^I, z, \lambda\}$, bank withdrawal strategies are optimal,*
- (iv) *given $\{D, z\}$, late consumer strategies are optimal.*

Next, we describe an equilibrium characterized by a set of D , D^I , z , $w^I(d^I, \lambda)$ and $w^L(d)$ and show that its allocation coincides with the first-best allocation derived before.

Consider the following equilibrium: The deposit and interbank deposit contracts are identical

and given by $D = D^I = (\bar{d}_1, \bar{d}_2)$, as determined by Condition 5, and the interbank deposits are given by $z = \bar{d}_1(\bar{\lambda} - \lambda_L)$. Banks withdraw early if their fraction of early consumers is low and wait if the fraction is high.⁵ Late consumers only withdraw at date $t = 2$.

For an illustration of the equilibrium, suppose that State S_1 occurs. The liquidity needs of early consumers of Bank A are $\bar{d}_1\lambda_H$. Given the high liquidity needs, Bank A calls in its interbank claims and withdraws $z\bar{d}_1 = \bar{d}_1(\bar{\lambda} - \lambda_L)$. The budget constraint Bank A faces at date $t = 1$ is $y + \bar{d}_1(\bar{\lambda} - \lambda_L) = \bar{d}_1\lambda_H$, which corresponds to $y = \bar{\lambda}\bar{d}_1$, the date-1 budget constraint of the social planner. Bank B with the low liquidity needs does not withdraw its interbank deposits, but pays out the amount requested by Bank A. Therefore, the budget constraint Bank B faces at date $t = 1$ is $\lambda_L\bar{d}_1 = y - \bar{d}_1(\bar{\lambda} - \lambda_L)$, which again coincides with the budget constraint of the social planner. Similarly one can show that the budget constraints at date $t = 2$ given the interbank deposits and withdrawal decision of the banks and the consumers specified above reduce to the one of the social planner. Thus, given the interbank contracts, interbank deposits and withdrawal decisions, the bank's investment problem reduces to the one of the social planner. The first-best allocation is implemented.

In order to prove existence of the characterized equilibrium, consider the following argument. Consumers choose the deposit contract that maximizes their expected utility. Due to perfect competition in the banking sector, this deposit contract has to be the constrained maximum that can be attained by a pair of banks given the investment technology and the instruments $\{D, D^I, z\}$. As shown, the values for $\{D, D^I, z\}$ suggested above attain the global first-best given the investment technology. Thus, there is no possible deviation by any pair of banks that would allow them to offer deposit contracts with the same level of expected utility but positive profits.

2.4 Contagion

Now, we introduce the possibility of bank runs and contagion. The decentralized first-best allocation is fragile in so far as a perturbation can lead to bankruptcy of all banks in the system.

⁵We assume that interbank deposits equal the minimum amount necessary to implement the first-best allocation. Interbank deposits could also be larger. However, if there is a small but positive probability on the perturbation state, which we introduce in the next section, then banks optimally hold only the minimum amount of interbank deposits necessary to implement liquidity insurance for states S_1 and S_2 in order to minimize the contagion risk.

Following Allen and Gale (2000), we perturb the banking system by introducing a third state that is assigned a zero-probability at date $t = 0$. This assumption is a departure from rational expectations. It allows us to focus on bankruptcy, contagion and ex-post intervention as it shuts down potential effects from ex-ante expectations on the real investment allocation.

Contracts and investment decisions at date $t = 0$ are the first-best allocation, as in the previous section. In the third state \bar{S} , aggregate liquidity needs are higher than expected. As illustrated in Table 2, there is an additional fraction ϵ of early consumers in Bank A. If states S_1 or S_2 occur, then the allocations at date $t = 1$ and $t = 2$ are first-best. However, if State \bar{S} occurs, the continuation equilibrium is different. As we are interested in reactions to bankruptcy and potential contagion, we concentrate our attention in the following on this state.

Table 2: Liquidity shocks with perturbation

	Bank A	Bank B	Probability
State S_1	λ_h	λ_l	0.5
State S_2	λ_l	λ_h	0.5
State \bar{S}	$\bar{\lambda} + \epsilon = \frac{\lambda_h + \lambda_l}{2} + \epsilon$	$\bar{\lambda}$	0

Given state \bar{S} , we can specify conditions under which firstly, bankruptcy of Bank A and secondly, contagion and hence bankruptcy of Bank B occurs. In order to make liquidation of the long asset the least attractive option, we assume that the following condition holds:

$$\frac{R}{r} \geq \frac{\bar{d}_2}{\bar{d}_1}. \quad (6)$$

From this a "pecking order" can be derived comparing the costs of obtaining date-1 consumption in terms of future consumption. Costs increase in the following order: short asset, interbank deposits, long assets. In state \bar{S} , the short assets of Bank A are not enough to satisfy its date-1 liquidity needs $\bar{d}_1(\bar{\lambda} + \epsilon)$ as the optimal investment decision at date $t = 0$ implies $y = \bar{d}_1\bar{\lambda}$. Therefore, facing the additional fraction of early withdrawers and given the assumption on the pecking order, Bank A calls in its interbank claims before starting to liquidate the long asset.

Bank A is bankrupt if by liquidating all assets, it still cannot meet demands of its depositors. More specifically, it goes bankrupt if it has to liquidate so much of the long asset in order to satisfy liquidity needs of early consumers that late consumers would receive a payoff smaller than d_1 . Anticipating this, late consumers then decide to withdraw their funds early and a bank

run occurs. Due to losses from early liquidation of the long asset, all consumers get less than the pay-offs originally promised to early depositors in the deposit contract and $d_1 < \bar{d}_1$. We can derive a condition for bankruptcy of Bank A:

$$\epsilon \bar{d}_1 > r \left((1 - y) - \frac{(1 - \bar{\lambda} - \epsilon) \bar{d}_1}{R} \right). \quad (7)$$

The term on the left hand side of Equation 7 represents the additional liquidity needs that cannot be satisfied by the investment in the short asset. As discussed, Bank A calls in its interbank claims. This, however, entails that also Bank B withdraws its interbank claims early as it faces more liquidity needs than it can satisfy with its short asset. Therefore, the interbank claims, which are of the same size, cancel out and do not appear in Equation 7. In order to avoid a run of its (late) depositors, Bank A must keep so much of the long asset that the return that it yields at date $t = 2$ is at least as high as to give every late consumer the pay-off promised to early consumers \bar{d}_1 . Therefore the bank must keep $\frac{(1 - \bar{\lambda} - \epsilon) \bar{d}_1}{R}$ units of the long asset. Only $(1 - y) - \frac{(1 - \bar{\lambda} - \epsilon) \bar{d}_1}{R}$ units of the long asset can be liquidated, which yield a return of $r \left((1 - y) - \frac{(1 - \bar{\lambda} - \epsilon) \bar{d}_1}{R} \right)$ at date $t = 1$. If these resources, the so-called buffer, are not enough to satisfy the unexpected demand of the fraction ϵ of additional early depositors, then Bank A is bankrupt.

Bankruptcy of Bank A has an impact on the other bank through the interbank deposits. Facing a higher than expected fraction of early consumers, Bank A calls in its deposits from Bank B. In order to meet the demand by Bank A, Bank B equally withdraws its deposits from Bank A. However, Bank A is bankrupt and is liquidated. Similar to Bank A's private depositors, Bank B receives only a pro rata share of Bank A's liquidation value. This share is necessarily smaller than the value of the actual claims ($r < 1$). Whether these losses are sufficient to cause bankruptcy of Bank B depends on whether the buffer of Bank B is large enough to provide sufficient liquidity at date $t = 1$. The following expression gives the bankruptcy condition for Bank B:

$$z(\bar{d}_1 - q^A) > r \left((1 - y) - \frac{(1 - \bar{\lambda}) \bar{d}_1}{R} \right), \quad (8)$$

where q^A represents the liquidation value of Bank A. This value is affected by bankruptcy of Bank B. If both banks go bankrupt, then each bank receives a pro rata share of the other's liquidation value. With symmetric interbank deposits, the mutual claims cancel out and each bank's liquidation value q^j is given by the value of the short asset plus the liquidation value of

the long asset, hence $q^j = \bar{q} = y + (1 - y)r$, $\forall j \in \{A, B\}$. If the bank hit by contagion (Bank B) does not go bankrupt, but fully repays the interbank deposit claims, then the liquidation value of Bank A is raised. This link is important for our later analysis. For bankruptcy of Bank B, Condition 8 has to hold in the case where Bank B fully repays Bank A's claims, hence when $q^A = \hat{q} = \frac{y+r(1-y)+z\bar{d}_1}{1+z}$. This is a sufficient condition for bankruptcy as lower liquidation values move this condition further towards bankruptcy.

Consider again Conditions 7 and 8 and assume that they hold with equality, i.e. that there is no bankruptcy. All other things equal, a lower liquidation value r or a lower return of the long asset R causes bankruptcy. The lower the liquidation value of the long asset, the more long assets have to be liquidated early in order to meet date-1 demand. Similarly, the lower the return on the long asset, the fewer long assets can be liquidated without lowering the pay-off of late depositors below \bar{d}_1 , which would cause a bank run. Moreover, a larger amount \bar{d}_1 promised to early depositors leads to bankruptcy. \bar{d}_1 depends on the relative risk aversion of the consumers. If the relative risk aversion coefficient is above 1, then the promised pay-off to early depositors exceeds the return of the storage technology, $\bar{d}_1 > 1$, and liquidity insurance is provided to early depositors.

2.5 Government intervention within one jurisdiction

From now on, we assume that the two bankruptcy conditions 7 and 8 hold. We cast the model in an international setting with two banks and two countries. Bank A is located in Country A, Bank B in Country B. Banks are linked internationally through interbank deposits as described before. Each country has a government that maximizes welfare of its population and that can decide to intervene when faced with potential bankruptcy of its domestic bank. In order to finance an intervention, it can tax the labor income of domestic agents at date $t=1$. It has to have a balanced budget.⁶ In this section, we discuss possible forms of government intervention and the determinants of optimal policy responses within a country. We formulate the decision problem of the government in a way that is valid for both countries.

At date $t=1$, a government that faces potential bankruptcy of its domestic bank chooses

⁶We assume that the government cannot borrow. If we allowed for this possibility, the government would have to raise taxes in the future to pay back its debt. The possibility to smooth taxes over time can reduce distortions. However, as long as raising funds is costly, the main trade-off remains unaffected.

between two actions.⁷ Firstly, it can decide not to intervene at all. Given our assumptions, this leads immediately to bankruptcy and liquidation of its bank. Each depositor receives a pro rata share q of the liquidated bank. Late consumers store the return and consume at date $t = 2$. If there is no intervention, which we denote by the subscript n , the welfare level V of the country is given by:

$$V_n = u(q). \quad (9)$$

Secondly, in order to prevent bankruptcy, the government can bail out its bankrupt bank. The cost of a bail-out can be derived from bankruptcy conditions 7 and 8, respectively. For a bail-out a government has to supply at least the additional liquidity that the bank needs in order to prevent a bank run. That is each depositor, independently of his type, has to receive at least \bar{d}_1 . If the bail-out sum is larger than this minimal amount, the bank liquidates less long assets and late consumers get a higher pay-off. Let b denote the pay-off that late depositors receive when the bank is bailed out. Let gap be the additional unexpected liquidity needs that occur in state \bar{S} and let λ be the fraction of early depositors that the bank faces. Then the general formula for the costs of a bail-out is given by:

$$G(b) = gap - r \left((1 - y) - \frac{(1 - \lambda)b}{R} \right). \quad (10)$$

We distinguish different degrees of bail-outs by the amount b that late depositors receive. We define a partial bail-out as the case where the minimum amount of liquidity is provided to avoid a bank run, i.e. all consumers of the bank receive \bar{d}_1 .⁸ In contrast, we define a full bail-out as a situation where so much liquidity is provided that late depositors receive the return they expected ex-ante, i.e. $b = \bar{d}_2$. Bail-out costs are linearly increasing in b . The optimal bail-out may be different from the two discussed above. It trades off the losses from liquidation with the costs of providing government funds. In order to finance the bail-out, the government taxes labor income at date $t = 1$. We assume that consumers observe the bail-out and know the tax rate $\tau \geq 0$, which the government imposes. With this information, agents decide upon how

⁷Notice that we do not consider the option of stopping convertibility. Stopping convertibility would avoid a bank run at no direct costs. However, a fraction ϵ of early consumers would not be able to withdraw, which would reduce their consumption to zero.

⁸A deposit insurance would guarantee the same pay-offs to consumer. However, there is a difference between a deposit insurance and a partial bail-out. In case of deposit insurance, the bank goes bankrupt and the government pays the difference between the liquidation value of a bank and the deposits. A partial bail-out is less costly as the provided funds avoid the early liquidation of some part of the long asset. For each unit of liquidity that the government provides, R/r funds are recovered.

much labor they are going to supply. Thus, taxes distort the agents' labor supply decision. The labor supply function is now given by:

$$n(\tau) = (1 - \tau) \frac{\kappa}{2}. \quad (11)$$

In order to raise a total amount of taxes G , the government has to set the tax rate so that:

$$G = \tau n(\tau) = \frac{\kappa}{2} \tau (1 - \tau). \quad (12)$$

This equation describes the Laffer curve the government faces. The government always chooses the smaller tax rate to finance any given spending. The tax rate $\tau^{max} = \frac{1}{2}$, which yields the maximum tax income, is independent of the parameter κ . In contrast, the maximum funds that the government can raise depend on κ and government intervention can only be financed if $G \leq G^{max} = \frac{\kappa}{8}$. In what follows we assume that this condition holds and each country can finance a domestic bail-out. In order to facilitate the notation, we let $\tau(G)$ denote the tax rate that has to be set if the government wants to collect G . Furthermore, we define $Z(G)$ as the total utility loss in terms of consumption due to distortionary taxation. As discussed before, for a tax rate of zero this effect is normalized to 0. Thus, for $\tau > 0$, this utility loss is strictly positive and is given by:

$$\begin{aligned} Z(G) &= -\eta \left(n(\tau(G))(1 - \tau(G)) - \frac{n(\tau(G))^2}{\kappa} - \frac{\kappa}{4} \right) \\ &= \frac{\kappa \eta}{4} \left[1 - \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{2}{\kappa} G} \right)^2 \right], \end{aligned} \quad (13)$$

where we substituted, in the second line of the expression, the optimal labor supply and tax rate, which are functions of G .⁹ If the government decides to intervene and to bail out the bank, then early consumers receive the promised amount \bar{d}_1 , while late consumer receive a pro rata share of the bank asset left at date $t = 2$. The latter, amount b , depends on how much liquidity was provided by the government. At the same time the government raises taxes to finance the bail-out. Due to equal taxation, each consumer incurs the same utility loss from

⁹It would be sufficient for $Z(G)$ to be increasing, convex and twice continuously differentiable. We assume a specific functional form for illustrative purposes.

taxation $Z(G(b)) > 0$, which increases with b . Welfare in the economy is then:

$$V_{bo}(b) = \lambda u(\bar{d}_1 - Z(G(b))) + (1 - \lambda)u(b - Z(G(b))). \quad (14)$$

When considering to do a bail-out, the government chooses $b \in \{\bar{d}_1, \bar{d}_2\}$ so as to maximize this equation. The first-order conditions of this problem imply:

$$\frac{\lambda u'(c_1)}{(1 - \lambda)u'(c_2)} = \frac{1 - Z'(G(b))G'(b)}{Z'(G(b))G'(b)} \quad (15)$$

A necessary condition for a bail-out beyond $b = \bar{d}_1$ to be optimal is that the utility of late consumers is increasing in b , thus $1 - Z'(G(b))G'(b)$ must be positive. In the two corner solutions $b = \bar{d}_1$ and $b = \bar{d}_2$, the FOC does not need to hold. We assume that when governments are indifferent between intervention and no intervention, they do not intervene, hence a government chooses a bail-out if $V_{bo}(b^*) > V_n$, where b^* is the solution to 15.

There is a notable difference between a partial bail-out where just enough liquidity is provided as to avoid bankruptcy and a bail-out where liquidity is provided beyond the minimum required amount $G(\bar{d}_1)$. From Equations 9 and 14 for a partial bail-out to be optimal, we must have that $d_1 - Z(G(\bar{d}_1)) > q$. A partial bail-out, if chosen by the government, thus implies a Pareto improvement. Any liquidity that is provided beyond $b = \bar{d}_1$ benefits only late depositors, while early depositors face a higher tax rate and thus a higher disutility from work. This can be optimal, because the utility gain from increasing late depositors' pay-offs may be bigger than the early consumers' utility loss. However, moving from partial bail-out to any other degree of bail-out never implies a Pareto improvement.¹⁰

Proposition 1 *Any additional liquidity provided beyond the amount required for a partial bail-out redistributes resources among agents, but does not induce a Pareto improvement.*

Proof. Omitted. ■

Whether no intervention or a bail-out yields higher welfare depends crucially on the curvature of the utility function and the function $Z(\cdot)$. They determine the trade-off a government faces. With changes in parameters, pay-offs are modified. Such changes may also imply that the bankruptcy conditions no longer hold. Assume in the following that the bankruptcy conditions

¹⁰This would not be the case if the government could tax early and late consumers differently.

continue to hold. From Equations 9 and 14 we see that an increase in the return on the long asset decreases the costs of a bail-out and increases pay-offs to late consumers, therein raising the overall welfare level from a bail-out relative to no intervention. Thus the incentives to intervene increase in R . The impact of the liquidation rate r on the optimal government intervention is ambiguous. A bigger loss from early liquidation decreases welfare levels for all forms of intervention. Relative changes depend on the exact parameter values.

The investment in the short asset y , decided upon at date $t = 0$, implicitly impacts the government decision as well. The welfare level given no intervention depends on the liquidation value of the bank, which is a function of y . The higher the amount invested in the short asset, the higher the liquidation value of the bank, the higher welfare if there is no intervention by the government. Moreover, y affects the costs of a bail-out. A higher y corresponds to a higher pay-off \bar{d}_1 promised to early consumers. Thus, liquidity needs or the *gap* increase with y as well.

2.6 Differences across banks and countries

The analysis in the previous section is valid for both countries and points out the trade-offs that each government faces within its own country when deciding on intervention. Now we analyze in more detail the differences between the two countries, which can lead to different optimal decisions of the governments. Country A is the source of the crisis. Its domestic bank faces an additional unexpected amount of early depositors ϵ . We call Country A therefore the *crisis country*. Bankruptcy of Bank A causes bankruptcy of Bank B. Therefore, we call Country B the *affected country*. Each government can decide to intervene or to bail-out the bank within its jurisdiction. Besides the direct effect of a bail-out on domestic welfare, there is a spillover effect on the welfare of the other country. This is due to the fact that banks are connected through interbank deposits. However the spillover effects of a bail-out are asymmetric and differ between the crisis country and the affected country. A bail-out of Bank A avoids contagion and saves Bank B. In contrast, a bail-out of Bank B increases the liquidation value of Bank A as interbank deposits are fully repaid. Figure 1 illustrates the setup and linkages of our model.

As a consequence of the different sources of bankruptcy across banks, bail-out costs differ between countries. Equation 10 is valid for both countries, but the *gap* and λ differ. From

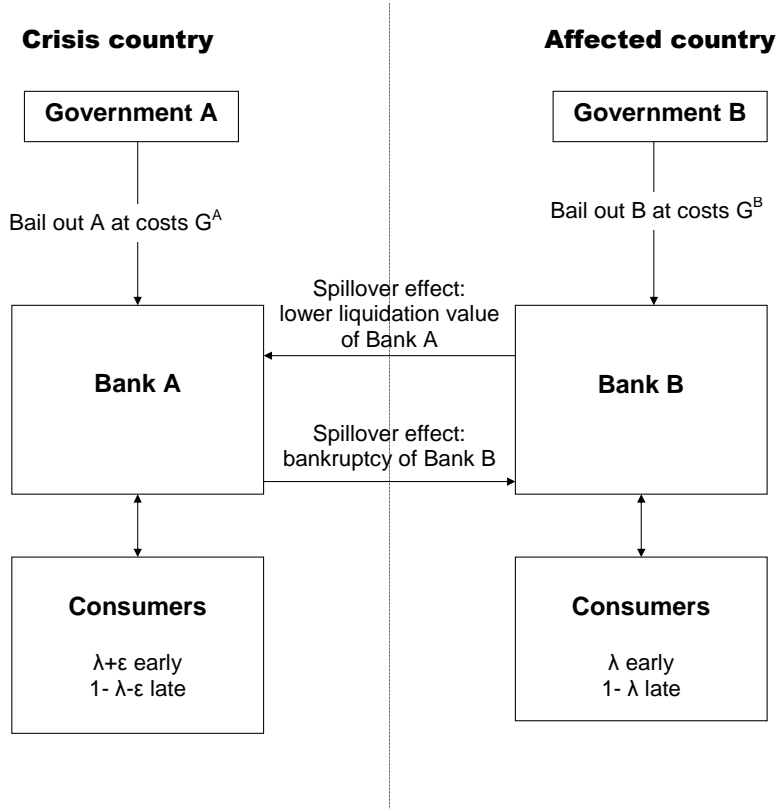


Figure 1: Model setup

Equation 7, the explicit bail-out costs for Bank A are:

$$G^A(b) = \epsilon \bar{d}_1 - r \left((1 - y) - \frac{(1 - \bar{\lambda} - \epsilon)b}{R} \right). \quad (16)$$

For Bank B, we have from Equation 8 that:

$$G^B(b) = z(\bar{d}_1 - \hat{q}) - r \left((1 - y) - \frac{(1 - \bar{\lambda})b}{R} \right). \quad (17)$$

While bankruptcy of Bank A is caused by unexpected liquidity needs creating a maturity mismatch, the reason for bankruptcy of Bank B lies in a real loss of assets.¹¹ In Country A, more individuals want to consume early. Funds however have been invested in the long asset at date

¹¹Suppose a government can raise non-discriminatory lump-sum taxes. Then, Country A would always prefer a bail-out over no intervention as there is a pure liquidity problem. The free-riding problem, though, remains and therefore no clear preference by Country A of a bail-out of Bank A compared to a bail-out of Bank B can be established. Bank B faces real losses in assets. Therefore, a bail-out of Bank B is desirable if the liquidation loss that can be avoided exceeds resources that have to be provided for the bail-out. It can be shown that this is always the case. We derive these results on lump-sum taxation in the Appendix.

$t = 0$. By providing funds, the government can avoid liquidation costs and due to the smaller fraction of late depositors can implicitly collect some return on the long asset. Given the same *gap*, a bail-out is cheaper in Country A.¹² Another difference between countries lies in the fraction of early and late depositors. Due to the exogenous shock, Bank A faces a larger fraction of early depositors $\bar{\lambda} + \epsilon$. Therefore, the government of Country A puts more weight on the welfare of early consumers than the government of Country B, where early consumers represent only a fraction of $\bar{\lambda}$. Due to asymmetric bail-out costs and different fractions of early and late depositors, the optimal decision between no intervention and bail-out as well as the choice of b typically differ between governments.

We state the welfare levels of each country separately. They depend on the actions taken by both governments. We denote welfare of country j by U_{s^A, s^B}^j , where the first subscript stands for Country A's intervention decision, while the second subscripts captures the action of Country B. We subsume the pair of actions taken by both countries by a . The general welfare function can then be formulated as:

$$V_a^j = \lambda^j u(c_1^j(a)) + (1 - \lambda^j) u(c_2^j(a, b)) \quad (18)$$

If neither country intervenes, all agents receive a pro rata share of the liquidation value of the bank. Each consumer, no matter in which bank it deposited its endowment, obtains \bar{q} as interbank claims offset each other:

$$V_{n,n}^A = V_{n,n}^B = u(\bar{q}). \quad (19)$$

If the government of the crisis country decides to bail-out its domestic bank, then contagion is avoided and the bank in Country B remains unaffected by the crisis in Country A. Welfare of Country A from bailing out its bank is:

$$V_{bo,n}^A(b) = (\bar{\lambda} + \epsilon) u(\bar{d}_1 - Z(G^A(b))) + (1 - \bar{\lambda} - \epsilon) u(b - Z(G^A(b))), \quad (20)$$

¹²As the share of late consumers is smaller than expected given the shock, the government in Country A could raise the return of late consumers beyond the expected level \bar{d}_2 by providing funds in order for $b > \bar{d}_2$. If the government could provide the funds conditional on becoming a residual claimant of the bank, it could collect the residual value of the bank after it has paid \bar{d}_2 to all late consumers, thereby potentially increasing efficiency. By restricting $b \in \{\bar{d}_1, \bar{d}_2\}$ in the optimization problem of the government, we do not consider this case.

where $G^A(b)$ is given by Equation 16. As there is no contagion and Bank B remains unaffected, there is no scope for intervention and Country B's welfare attains the maximum:

$$V_{bo,n}^B = \bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(\bar{d}_2). \quad (21)$$

However, if Country A does not intervene, there is contagion and the government of Country B has to decide whether or not to intervene. If Country B does a bail-out, Country A's welfare is raised compared to the case where both banks go bankrupt. This is because, as Bank B is saved and does not go bankrupt, it is able to pay the full amount of the interbank claims. Instead of a pro rata share of Bank B's liquidation value, Bank A now obtains $z\bar{d}_1$. Thus Bank A's liquidation value increases to $q^A = \hat{q} = \frac{y+r(1-y)+z\bar{d}_1}{1+z} > \bar{q}$ and welfare of Country A is given by:

$$V_{n,bo}^A = u(\hat{q}). \quad (22)$$

The welfare level of the affected country, if it does a bail-out, is:

$$V_{n,bo}^B(b) = \bar{\lambda}u(\bar{d}_1 - Z(G^B(b))) + (1 - \bar{\lambda})u(b - Z(G^B(b))), \quad (23)$$

where $G^B(b)$ is given by Equation 17. Note that the bail-out of Bank B has a positive feedback effect on itself. Because Bank B does not go bankrupt, it can fully repay Bank A's claims. This in turn, raises the liquidation value of Bank A, of which Bank B receives a pro rata share.

3 Centralized versus decentralized decision-making

In this section, we study and compare possible equilibria given decentralized and centralized decision making, respectively. This, in turn, allows us to evaluate the role of government cooperation in times of international banking crisis. As a benchmark, we consider the decentralized solution with strategic interaction between governments, where governments play a sequential bail-out game. Then, we introduce a central authority with the power to mandate actions to be taken by both governments. We analyze whether and to what extent this central authority can improve upon the non-cooperative equilibrium.¹³

¹³In the Appendix, we study the game with simultaneous moves by the governments.

3.1 Non-cooperative bail-out game

When there is no coordination, each government decides on its own whether and how to intervene. Strategic interaction arises as welfare from each form of government intervention depends on the action of the other government. Note that the welfare level of each country, however, is independent of the liquidity that is provided for a bail-out of the foreign bank. Therefore, b is not a strategic variable. The bail-out game in extensive form is illustrated in Figure 2. The set of strategies of the government in Country A is given by $S_A = \{n, bo\}$ and in Country B by $S_B = \{n, bo\}$. We consider subgame-perfect Nash equilibria in pure strategies of the game with

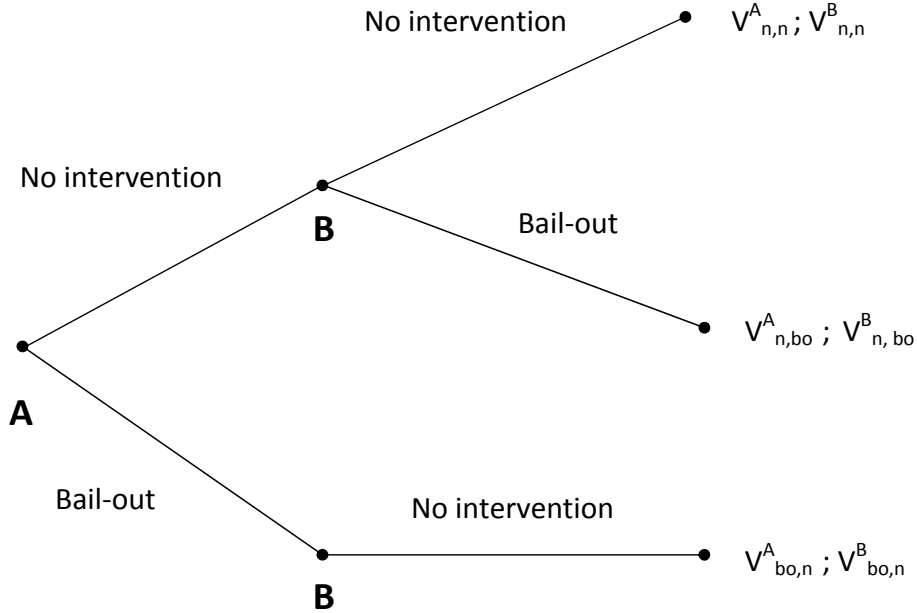


Figure 2: Bail-out game in extensive form

sequential moves. The crisis country moves first and the affected country is the follower.

Definition 2 *The profile $a^* \equiv (s^{A*}, s^{B*})$ is a subgame-perfect Nash equilibrium (SPNE) of the game described in Figure 2 iff*

- (i) *the government in Country B maximizes its domestic welfare, given the strategy of Country A, i.e. $V^B(a^*) \geq V^B(s^B, s^{A*}) \forall s^B \in S^B$,*
- (ii) *the government in Country A maximizes its domestic welfare, given the strategy of Country B, i.e. $V^A(a^*) \geq V^A(s^A, s^{B*}) \forall s^A \in S^A$,*

(iii) and a^* is a Nash equilibrium in every proper subgame.

There are three possible equilibria of the sequential game. In the following we state conditions under which each of these three possible outcomes of the game occurs:

Proposition 2 (i) $a^* = (n, n)$ is a SPNE iff $V_{n,bo}^B \leq V_{n,n}^B$ and $V_{bo,n}^A \leq V_{n,n}^A$.

(ii) $a^* = (n, bo)$ is a SPNE iff $V_{n,bo}^B > V_{n,n}^B$ and $V_{bo,n}^A \leq V_{n,bo}^A$.

(iii) $a^* = (bo, n)$ is a SPNE iff $V_{bo,n}^A > V_{n,bo}^A$ or $V_{n,bo}^B \leq V_{n,n}^B$ and $V_{bo,n}^A > V_{n,n}^A$.

Proof. Note that, from Equations 19 to 23 it follows that $V_{n,bo}^A > V_{n,n}^A$ and $V_{bo,n}^B > V_{n,n}^B$ as well as $V_{bo,n}^B > V_{n,bo}^B$ and $V_{bo,n}^B = V_{bo,bo}^B$. ■

3.2 Central authority with mandating power

Now we derive the optimal decision of a central authority with a mandate to decide upon intervention. As before, three possible pairs of actions a are possible: no intervention of both countries (n,n) , bail-out of Bank A (bo, n) or bail-out of Bank B (n, bo) . The objective function of the central authority is the weighed sum of national welfare levels. Attributing welfare weight Θ^j to country j , it solves the following problem:

$$\max_{a \in \{(n,n), (n,bo), (bo,n)\}} V = \sum_{j \in \{A,B\}} \Theta^j V_a^j(d_1^j(a), d_2^j(a, b), Z(G^j)). \quad (24)$$

The pair of actions which maximizes this objective is denoted by a' . It is not necessary for the central authority to have the power to mandate b as governments automatically choose the optimal degree of the bail-out (see Equation 15).

Bail-out costs differ between banks. Therefore, although a bail-out of Bank A prevents contagion and raises Country B's welfare to the maximum, a bail-out of Bank A does not necessarily dominate a bail-out of Bank B. If $G^A(b)$ is sufficiently large, the optimal solution to the central authority's problem can imply saving Bank B only. Therefore, without any restrictions on parameters, any of the three possible combinations of government actions can be optimal.

3.3 Inefficiencies in the bail-out game

We compare the solution of the central authority with mandating power with the equilibrium of the sequential game. For this we assume that the welfare weights attributed to each country are the same. In a first step we study relations between outcomes of the sequential game and decisions taken by the central authority. Proposition 3 states which actions can be the solution to Expression 24 for a given equilibrium of the sequential game:

Proposition 3 *(i) If the SPNE is $a^* = (bo, n)$, then this equilibrium coincides with the optimal solution of the central authority a' .*

(ii) If the SPNE is $a^ = (n, bo)$, then $a' \in \{(bo, n), (n, bo)\}$.*

(iii) If the SPNE is $a^ = (n, n)$, then $a' \in \{(bo, n), (n, bo), (n, n)\}$.*

Proof. See the Appendix. ■

If (bo, n) is the SPNE, a central authority chooses the same outcome. However, when (n, bo) is the SPNE, a bail-out of Bank A or Bank B can be optimal. Finally, all actions can be optimal to be mandated when (n, n) is the equilibrium.¹⁴

Next, we consider the relations in the opposite direction and ask which actions can be the equilibrium of the sequential game, if the central authority finds a certain sequence of actions a' optimal:

Corollary 1 *(i) If $a' = (bo, n)$, then all actions $a^* \in \{(bo, n), (n, bo), (n, n)\}$ can be the SPNE of the bail-out game.*

(ii) If $a' = (n, bo)$, then the actions $a^ \in \{(n, bo), (n, n)\}$ can be the SPNE of the bail-out game.*

(iii) If $a' = (n, n)$, then $a^ = (n, n)$ is the only SPNE of the bail-out game.*

Proof. Follows directly from Proposition 3. ■

First, if the central authority finds a bail-out of Bank A optimal, then all three outcomes are possible equilibria of the sequential game and $a^* \in \{(n, n); (n, bo); (bo, n)\}$. Second, if a central authority does not find a bail-out of Bank A optimal, then it follows that the government in Country A itself does not choose to bail-out its domestic bank either. Finally, if the

¹⁴The situation in which the bankruptcy condition of Country B, Condition 8, holds and $a' = (bo, n)$ can be interpreted as representing the case of "too big to fail". While saving Bank A might not be optimal per se, i.e. only taking into account effects on Bank A depositors, a bail-out of Bank A might be optimal when the potential failure of Bank B is taken into account, too.

central authority finds that no country should intervene, then $a^* = (n, n)$ is also the SPNE of the sequential game. This follows from the fact that for the central authority to choose no intervention, we must have $u(\bar{q}) > V_{bo,n}^A$ and $u(\bar{q}) > V_{n,bo}^B$, a situation in which neither Country A nor Country B choose a bail-out.

Note that all distortions are towards to little intervention. If no intervention is optimal in both countries, there is no bail-out in the non-cooperative equilibrium. It is only possible that the "wrong" bank is the subject of the bail-out in that a bail-out of Bank B is implemented although a bail-out of Bank A maximizes overall welfare. Suboptimal decisions in the form of $a^* \neq a'$ only occur if a central authority finds a bail-out optimal and if Country A does not choose a bail-out in the bail-out game.

When comparing decisions in the sequential game with those taken by a central authority with mandating power, two sources of inefficiencies can be identified. First, due to the interbank linkages, there are spillover effects (*externalities*), which are not taken into account by the governments. Second, there is a *free-riding* problem due to the sequential nature of the bail-out game.¹⁵ The crisis country may not bail out its domestic bank because it knows that then the affected country will do a bail-out. As the first mover it can free ride on the bail-out carried out by Country B. This is captured in the following proposition:

Proposition 4 *An anticipated bail-out in the affected country lowers the incentives for a bail-out in the crisis country.*

Proof. Country A does a bail-out iff $V_{bo,n}^A > V_{n,.}^A$.

$$V_{n,.}^A = \begin{cases} V_{n,n}^A & \text{if Country B does not intervene} \\ V_{n,bo}^A & \text{if Country B does a bail-out,} \end{cases}$$

and $V_{n,bo}^A > V_{n,n}^A$. ■

Given that the crisis country does not intervene, an anticipated bail-out of the affected country raises the welfare level in the crisis country because Bank B can fully repay Bank A's interbank claims, which raises Bank A's liquidation value. The magnitude of the effect of a bail-out in the affected country on the crisis country is determined by the size of the interbank

¹⁵In the simultaneous bail-out game, there are multiple Nash equilibria. Instead of the free-riding problem, a coordination problem may occur.

deposits:

Proposition 5 (i) *The incentives for a bail-out in the affected country decrease in the interbank deposits z .*

(ii) *If the affected country bails out its domestic bank, then the incentives for a bail-out in the crisis country decrease in the interbank deposits z .*

Proof.

$$(i) \frac{\partial G^B(b)}{\partial z} = \bar{d}_1 - q^A > 0 \Rightarrow \frac{\partial(V_{n,bo}^B - V_{n,n}^B)}{\partial z} > 0.$$

$$(ii) \frac{\partial \hat{q}}{\partial z} = \frac{\bar{d}_1 - (y+r(1-y))}{(1+z)^2} > 0 \Rightarrow \frac{\partial(V_{bo,n}^A - V_{n,bo}^A)}{\partial z} < 0. \blacksquare$$

Interbank deposits are a function of the investment in the short asset y and the anticipated date-0 uncertainty captured by $\bar{\lambda} - \lambda_L$. Note from Expression 17 that with increasing interbank deposits z , a bail-out in Country B becomes more costly as the loss from bankruptcy of Bank A grows. This makes it less attractive for the affected country to bail out its bank.

A central authority that can dictate actions internalizes the externalities and eliminates the free-riding problem. This form of coordination can therefore improve global welfare.

4 Cross-country deposits and country sizes

In this section, we introduce cross-country deposits as an additional form of international linkages, i.e. banks compete for customers in both countries who can decide freely on where to deposit their endowment. Furthermore, we allow for differences in country size.

In the previous section, we identified two sources of inefficiency that can arise in the bail-out game: externalities due to spillovers and free-riding due to the sequential nature of the game. As discussed, they imply that a central authority with mandating power can in some cases improve upon the non-cooperative equilibrium. In the following, we study how the presence of cross-country deposits and differences in country size affect the outcome of the non-cooperative game and the decision taken by a central authority, as well as the two sources of inefficiencies. We find that with equal country sizes the incentives to free ride, in general, decrease in the share of cross-border deposit holdings. The optimal choice of b decreases in the size of cross-country deposits. Finally, asymmetric country sizes affect optimal decisions as they imply different tax distortions given the same level of government expenditures.

4.1 Extended model setup

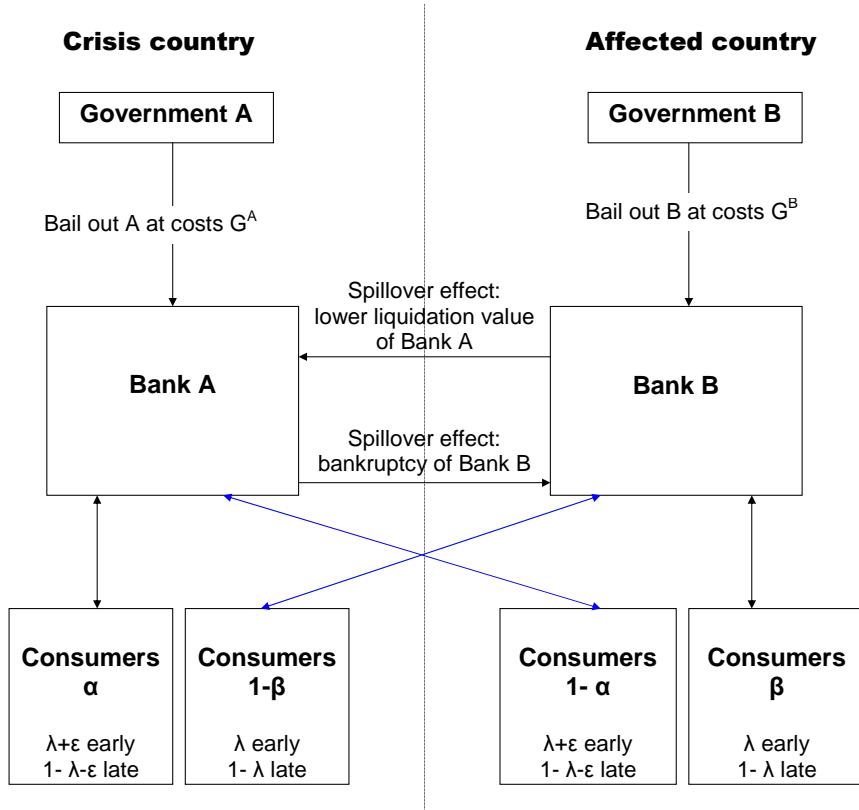


Figure 3: Extended model setup

The modified setup with cross-country deposits is illustrated in Figure 4. Let α (β) denote the fraction of depositors of Bank A (Bank B) that live in Country A (Country B) and let $(1 - \alpha)$ ($(1 - \beta)$) denote the fraction of agents that are depositors of Bank A (Bank B) that live in Country B (Country A).¹⁶ Banks remain of equal size, each hosting a unit mass of deposits. We assume that the liquidity shock ϵ hits a bank.¹⁷ Therefore, bail-out costs G are independent of the distribution of depositors. However, how easily a bail-out can be financed depends on the tax base of a country, hence its size. The smaller the population, the higher the tax rate required to raise the funds for a bail-out, the higher the distortion. Countries differ in size if $\alpha \neq \beta$. The population of Country A is $P^A = \alpha + (1 - \beta)$. In Country B it is $P^B = \beta + (1 - \alpha)$. With

¹⁶Ex-ante agents are indifferent where to deposit their endowments. We assume that each agent deposits its entire endowment either abroad or at home.

¹⁷An alternative would be a shock hitting a country. This would lead to shocks in form of additional early depositors in both banks, i.e. $\epsilon \alpha$ in Bank A and $\epsilon(1 - \alpha)$ in Bank B for the case where the shock hits nationals of Country A.

asymmetric country sizes, the disutility from work becomes country-specific and depends on the population size P^j . Substituting for the tax rate $\tau(G, P^j)$ we obtain the following expression:

$$Z^j(G, P^j) = \frac{\kappa\eta}{4} \left[1 - \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{2}{P^j\kappa}G} \right)^2 \right]. \quad (25)$$

Cross-country deposits change the bail-out game in three ways. Firstly, governments now take the spillover effects into account because they care about domestic consumers that invested abroad. The intervention has, through the spillover, a direct impact on their pay-offs. Secondly, the amount of liquidity b that is provided by a government enters the welfare function of the other country. Without cross-country deposits, a country's welfare was only impacted by the bail-out decision that the other country took and not by b . Nevertheless, b is as before not a strategic variable.¹⁸ When deciding upon an action, each government takes the optimal b^* of the other country as given. Thirdly, as liquidity shocks are attributed to a bank rather than a country, the fraction of early and late depositors of each country in State \bar{S} is altered. The fraction of early depositors in Country A is reduced and is only $\alpha(\lambda + \epsilon) + (1 - \beta)\lambda$, while the equivalent fraction in Country B is increased and is $(1 - \alpha)(\lambda + \epsilon) + \beta\lambda$. As a consequence the welfare weights that are attributed to early and late consumers are modified.

The derivation of the pay-offs of the bail-out game with cross-country deposits is straightforward. If both countries do not take any action, total welfare of Country-A agents is

$$V_{n,n}^A = \alpha u(\bar{q}) + (1 - \beta)u(\bar{q}). \quad (26)$$

For Country B we have equivalently:

$$V_{n,n}^B = (1 - \alpha)u(\bar{q}) + \beta u(\bar{q}). \quad (27)$$

If both countries are of equal size, then both expressions reduce to Equation 19. If Country A

¹⁸Consider two possible cases. i) If country A does a bail-out, then there is no action by Country B. ii) If Country B does a bail-out, there is no strategic effect as it is the second mover without commitment power.

bails out its bank, it obtains the following welfare level:

$$V_{bo,n}^A(b) = \alpha [(\bar{\lambda} + \epsilon)u(\bar{d}_1 - Z^A(G^A(b))) + (1 - \bar{\lambda} - \epsilon)u(b - Z^A(G^A(b)))] + \quad (28)$$

$$+ (1 - \beta) [\bar{\lambda}u(\bar{d}_1 - Z^A(G^A(b))) + (1 - \bar{\lambda})u(\bar{d}_2 - Z^A(G^A(b)))]$$

Country B benefits from the bail-out in Country A because firstly, there is no need for intervention as contagion is avoided, and secondly, because domestic consumers that deposited in Bank A receive higher pay-offs than under bankruptcy, namely the ones expected at date $t = 0$. The welfare in Country B is:

$$V_{bo,n}^B(b) = (1 - \alpha) [(\bar{\lambda} + \epsilon)u(\bar{d}_1) + (1 - \bar{\lambda} - \epsilon)u(b)] + \beta [\bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(\bar{d}_2)]. \quad (29)$$

If Country A does not intervene but Country B bails out its bank, welfare in Country A is:

$$V_{n,bo}^A(b) = \alpha u(\hat{q}) + (1 - \beta) [\bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(b)]. \quad (30)$$

Utility of Country-A consumers is positively impacted when Country B bails out its bank. In addition to domestic consumers holding deposits abroad, agents having invested domestically benefit through the positive effect of the bail-out on the liquidation value of Bank A as $\hat{q} > \bar{q}$. Welfare in Country B is:

$$V_{n,bo}^B(b) = (1 - \alpha)u(\hat{q} - Z^B(G^B(b))) + \beta [\bar{\lambda}u(\bar{d}_1 - Z^B(G^B(b))) + (1 - \bar{\lambda})u(b - Z^B(G^B(b)))] . \quad (31)$$

Proposition 2 also pins down the equilibrium with cross-country deposits.

4.2 Cross-country deposits, country sizes and inefficiencies

To continue with, we analyze which impact cross-country deposits and differences in country size have on the decision of the central authority, the outcome of the non-cooperative game and the two sources of inefficiencies discussed before. If the central authority gives equal weight to every consumer and country sizes are equal, cross-country deposits do not change its problem. Differences in country size, in contrast, have an effect as they imply different tax bases and thus country-specific tax distortions. Cross-country deposits also affect the decision by each country

on how much liquidity to provide in a bail-out.¹⁹ Due to the fact that not all domestic agents deposit in the domestic bank, an additional unit of liquidity has a lower marginal contribution to national welfare and b^* will be lower than without cross-country deposits:

Proposition 6 *For a given country size, the smaller the fraction of domestically held deposits, the lower the optimal liquidity b^* provided by the government in case of a bail-out.*

Proof. See the Appendix. ■

Furthermore, cross-country deposits have an impact on the non-cooperative outcome. As the incentives for bail-outs change, the extent of the free-riding problem changes as well. For equally sized countries, the effects can be summarized in the following proposition:

Proposition 7 *Suppose countries are of equal size ($\alpha = \beta$). Then, an increase in the fraction of deposits abroad*

(i) decreases the incentives for a bail-out in the affected country.

(ii) increases the incentives for a bail-out in the crisis country if it anticipates no bail-out in the affected country.

Proof. See the Appendix. ■

The incentives for Country B to do a bail-out decrease with the fraction of deposits abroad. This is the case because the direct effect of a bail-out on consumers who have invested domestically is larger than the indirect effect of a bail-out on domestic deposit holdings abroad through the rise in the liquidation value of Bank A. While a partial bail-out raises pay-offs by $\bar{d}_1 - \bar{q}$ for Bank-B depositors, the increase for Bank-A depositors is only a fraction of that, $\hat{q} - \bar{q} = \frac{z}{1+z}(\bar{d}_1 - \bar{q})$. If $b^* > \bar{d}_1$, late consumers that invested domestically benefit more than early consumers, while the additional liquidity support does not impact the pay-off to consumers that invested abroad.

If Country A anticipates that Country B will not bail out its bank, then the incentives of Country A to do a bail-out increase with the fraction of domestic deposits abroad. A bail-out in Country A can avoid contagion and has therefore a large effect on the pay-offs to Country-A consumers that invested abroad. With a growing fraction of domestic endowments deposited

¹⁹If the central authority could also mandate b , this could improve welfare as it would take the externalities from the liquidity provision into account.

in Bank B, the benefits from a bail-out increase for Country A. This is due to the fact that a partial bail-out in Country A is enough to guarantee that late depositors that invested in Bank B receive the originally promised amount \bar{d}_2 . In order to induce the same welfare of domestic depositors, costs are lower when we have $\beta > 0$. Therefore, given Country B is not willing to bail-out its bank, the incentives of the government in Country A for a bail-out of Bank A increase in β .

If Country A anticipates that there will be a bail-out in Country B, then the effect of the fraction of deposits held abroad on its incentives to bail-out Bank A is ambiguous. The welfare of Country A from a domestic bail-out increases with the fraction of agents that have invested abroad. At the same time, however, the benefits for Country-A depositors from a bail-out of Bank B by Country B increase. How the optimal decision changes with β is ambiguous. If there is a bail-out of Bank B, then early depositors of Bank B receive \bar{d}_1 , while late depositors get the pay-off b . If Country A avoids contagion incurring cost $G^A(b)$, then late consumers of Country A with endowments in Bank B receive the full promised return \bar{d}_2 . Therefore, a bail-out by Country A can be optimal as it can result in a higher return for its late depositors that invested in Bank B. The exact effect of an increase in domestic Bank-B depositors on the decision of Country A therefore depends on the bail-out costs and the optimal bail-out level chosen by Country B. Clearly, the lower the liquidity provided to Bank B by Government B, the lower the pay-off to late depositors of Bank B, the higher the incentive of Government A to bail out its domestic bank in order to avoid contagion.

Next, we study the effect of country size. For the special case where 50% of consumers in each country hold deposits abroad, the following proposition can be stated:

Proposition 8 *Suppose countries hold an equal share of deposits at home and abroad ($\alpha = 1 - \beta$). Then, holding b constant,*

- (i) the incentives for a bail-out in the crisis country increases with its size (α),*
- (ii) the incentives for a bail-out in the affected country increases with its size (β).*

Proof. See the Appendix. ■

In the model country size corresponds to the size of the tax base. If α is bigger than β , the crisis country is bigger than the affected country. As a consequence, to cover the same costs of intervention, the necessary tax rate and therefore distortions from taxation are lower in the crisis country than in the affected country. This makes a bail-out in the crisis country relatively more

attractive. At the same time, the free-riding problem is smaller, as a bail-out in the affected country is less likely if its tax base is smaller.

So far we have isolated the effects of cross-country deposits and differences in country sizes. For other combinations of parameters, these two effects interact. We find that, whether cross-country deposits tend to reinforce inefficiencies or alleviate them, depends on the nature of the asymmetry between countries.

If $1 - \beta \geq \alpha > 1 - \alpha \geq \beta$, then the crisis country is larger than the affected country and the majority of domestic agents holds deposits abroad. The size of the crisis country increases Government A's willingness to finance a bail-out. The fact that most of the domestic endowments are deposited abroad reinforces the positive effect of size because by bailing out Bank A domestic consumers that invested abroad are saved at the same time while the small tax base of Country B makes a bail-out there unlikely.

If $1 - \alpha \geq \beta > 1 - \beta \geq \alpha$, then the situation is the other way around. The crisis country is smaller than the affected country, but still the majority of depositors in the domestic bank are foreigners. In this case, it will be difficult for Country A to finance a bail-out of its domestic bank due to the small tax base. At the same time, it is easier for Country B to finance the bail-out of Bank B due to the larger size of the country. By a bail-out of Bank B, in turn, the majority of the deposits of Country A, which are abroad, is saved, and through this indirect effect, the incentives for bail-out in Country A can decrease.

5 Fiscal burden sharing

In the context of the European initiative toward a new financial architecture, it has been argued that fiscal burden sharing is required for efficient crisis management (see for example De Larosiere Report (2009)). In this section, we consider a central authority with mandating *and* fiscal power, i.e. it can now decide on the action to be taken and set a contribution to be financed by each country. We study how the new instrument of fiscal burden sharing can improve efficiency compared to the non-cooperative outcome. As discussed, a central authority without fiscal power can improve global welfare by mandating the efficient actions as this removes the inefficiencies due to externalities and free-riding. Introducing burden sharing can further improve upon the equilibrium allocation.

Without joint financing, there is an inefficiency due to *no burden sharing*, which comes from the convexity of function $Z(\cdot)$ due to labor distortions. A bail-out becomes cheaper in utility terms when it is financed by both countries because these distortions are reduced. Now, even if the optimal actions prescribed by a central authority coincide with the outcome of the sequential game, i.e. $a^* = a'$, a situation in which the central authority without fiscal power could not improve upon the equilibrium global welfare, the central authority now brings an improvement by implementing optimal burden sharing. The possibility of burden sharing increases the number of cases in which a bail-out is desirable. That is there are cases in which a central authority without fiscal power may decide for no intervention, while a central authority with fiscal power may choose to mandate a bail-out. Compared to the optimal solution chosen by a central authority with fiscal power, the equilibrium of the sequential game is, as before, distorted towards too little intervention and Proposition 3 remains valid.

No cross-country deposits We start with an analysis of the problem of a central authority with fiscal power when there are no cross-country deposits. The central authority decides upon an intervention and a burden sharing rule. If a bail-out is optimal, the authority chooses the bail-out level b and the country-specific contributions X^A and X^B such that the sum of the contributions equals the funds required for the bail-out $G(a,b)$, where $G(a,b)$ is given by Equation 16 if $a = (bo, n)$ or by Equation 17 if $a = (n, bo)$. We restrict contributions to be non-negative. The central authority solves the following maximization problem:

$$\begin{aligned}
\max_{a \in \{(n,n), (n,bo), (bo,n)\}, b \leq \bar{d}_2, X^A} \quad & V = \sum_{j \in \{A,B\}} \Theta^j V_a^j(d_1^j(a), d_2^j(a,b), Z(X^j)) \\
s.t. \quad & G(a,b) = X^A + X^B, \\
& X^A \geq 0, \\
& X^B \geq 0, \\
& Z(X^j) = \frac{\kappa\eta}{4} \left[1 - \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{2}{\kappa} X^j} \right)^2 \right], \forall j \in \{A, B\}.
\end{aligned} \tag{32}$$

The first-order conditions with respect to the contribution levels imply:

$$\frac{\Theta^A}{\Theta^B} = \frac{\bar{\lambda} u'(d_1^B(a) - Z(X^B)) + (1 - \bar{\lambda}) u'(d_2^B(a,b) - Z(X^B))}{(\bar{\lambda} + \epsilon) u'(d_1^A(a) - Z(X^A)) + (1 - \bar{\lambda} - \epsilon) u'(d_2^A(a,b) - Z(X^A))} \frac{Z'(X^B)}{Z'(X^A)}. \tag{33}$$

By setting contribution levels, the central authority can induce discriminatory taxation. On the one hand, disutilities from labor taxation, which in our setup are independent of individual income levels, prescribe an equalization of contribution levels between countries, i.e. tax smoothing. On the other hand, differences in income levels between countries, resulting from asymmetric effects of the banking crisis, give rise to a consumption smoothing motive. Thus, a central authority trades off a tax smoothing *and* a consumption smoothing motive. Given a banking crisis, Country A is always poorer than Country B. Due to this fact, we can derive the following result regarding contribution levels:

Proposition 9 *Suppose countries have the same welfare weights. Then, under a central authority with fiscal power, the contribution for a bail-out X^B of the affected country will be larger than the contribution X^A of the crisis country .*

Proof. See the Appendix. ■

Note that the ability to induce discriminatory taxes is an additional instrument in the international context, which is not available in a national crisis. Imagine a closed economy model where the two countries integrate and form one country with one government. Then the maximization problem of the government that hosts both Banks A and B is the same as the problem of the central authority stated above with the exception that the government cannot set discriminatory taxes, i.e. there is perfect tax-smoothing. The depositors of each bank have to bear the same distortion from taxation and $X^A = X^B = G(a, b)/2$. As consumers have different pay-offs in case of a banking crisis, discriminatory taxation is desirable. A central authority has thus an advantage relative to the case of full integration. The additional policy instrument of tax discrimination allows it to attain a higher welfare level.

The central authority also chooses the degree of the bail-out b . Note that, in general, the authority will mandate a level of liquidity provision different from the choice that a government would make on its own as it can raise taxes more efficiently. The central authority's first-order condition for b is stated in the Appendix.

With cross-country deposits The problem of the central authority changes with the introduction of cross-country deposits. The relative income of the two countries depends on α and β . Cross-country deposits alter the fraction of early and late depositors each country has as well as the pay-offs to them. Moreover, the degree of the bail-out b now impacts the welfare level

of both countries. In addition, the ability of each country to raise taxes, which is characterized by the country-specific function $Z^j(\cdot)$, is affected when countries differ in size. These factors modify the consumption smoothing versus tax smoothing trade-off that a central authority with fiscal power faces. Consequently, Proposition 9 does not hold with cross-country deposits.²⁰

Unilateral financing There is the possibility that a country may not be able to finance a bail-out on its own, which we have ruled out so far. This is the case when the maximum tax income it can raise is not sufficient to finance the costs of a bail-out, i.e. $G^{max} < G^j(b)$. With cross-country deposits, the relative size of banks to population is no longer bounded from above. The size of a domestic bank can exceed the country size. This makes the case of an absolute financing constraint more likely.

Such a financing constraint reduces the strategy set of the governments as well as the set of possible equilibria. Thereby, it can improve welfare if there is a free-riding problem. If Country B is not able to finance a bail-out, the free-riding problem simply disappears (see Appendix E). However, it may also be desirable to circumvent a financing constraint. If a breakdown of the financial system can be avoided, global welfare may be boosted by a bail-out. A central authority with mandating power alone cannot bypass a financing constraint as the financial burden between countries is not shared. Only an authority that can also set contribution levels can make a bail-out feasible in such a situation. This implies that burden sharing becomes more important when country sizes are very asymmetric.

6 Contracts

So far we have analyzed the non-cooperative solution and contrasted it with the outcomes under a central planner with fiscal power and/or mandating power. Our focus has been on revealing inefficiencies without cooperation. In this section, we investigate an additional form of cooperation: contracts. While a central authority corresponds to an ex-ante agreement on how to coordinate actions during a crisis, contracts reflect ex-post cooperation. We address the question what contracts between governments that are signed after the crisis has occurred can achieve compared to a central authority.

²⁰In our setting, the ability to tax people according to the bank they deposited in could bring an improvement when we have cross-country deposits.

Contracts specify actions to be taken and a burden sharing rule. We model the negotiation process between governments via Nash bargaining with symmetric negotiation power. As contracts are voluntary, governments only sign a contract if doing so weakly improves their domestic welfare level. The Nash bargaining problem is as follows:

$$\begin{aligned} \max_{a \in \{(n,bo),(bo,n)\}, X^A} & (V^A(a, b, X^A) - V^B(a^*)) (V^B(a, b, X^B) - V^B(a^*)) & (34) \\ \text{s.t. } & G(a, b) = X^A + X^B. \end{aligned}$$

If a contract is signed, it implies a Pareto improvement compared to the non-cooperative benchmark. One necessary condition for a Pareto improvement is that the actions \tilde{a} that are prescribed by the contract differ from the equilibrium actions a^* of the bail-out game. A contract cannot be an agreement on burden sharing or a different degree of bail-out alone as the participation constraint of one government would be violated. A second necessary condition is that the country where the bail-out does not take place helps finance the bail-out in the other country. This follows from the fact that governments maximize domestic welfare in the bail-out game. A change in actions without compensation must therefore reduce domestic welfare of at least one country. From these two conditions together with Proposition 3, it follows that there are two different outcomes of the non-cooperative game that each allow for specific types of contracts to be signed. We summarize our findings in the following proposition:

Proposition 10 (i) *If $a^* = (n, n)$ and contracts allow for a Pareto improvement, then $\tilde{a} = (n, bo)$ with $\tilde{X}^A > 0$ or $\tilde{a} = (bo, n)$ with $\tilde{X}^B > 0$.*
(ii) *If $a^* = (n, bo)$ and contracts allow for a Pareto improvement, then $\tilde{a} = (bo, n)$ with $\tilde{X}^B > 0$.*

Proof. See the Appendix. ■

Case (i) captures situations where neither country intervenes, but welfare can be improved by a bail-out. In order for Country B to agree on bailing out its domestic bank, Country A has to subsidize the bail-out and vice versa. In Case (ii), Country B would bail-out its bank without any cooperation between countries. However, each country's welfare can be increased if Bank A instead of Bank B is bailed out and Country B subsidizes the bail-out.

The first-order conditions of the Nash bargaining problem imply:

$$\frac{Z'(X^B)}{Z'(X^A)} = \frac{(\bar{\lambda} + \epsilon)u'(d_1(a) - Z(X^A)) + (1 - \bar{\lambda} - \epsilon)u'(d_2(a, b) - Z(X^A))}{\bar{\lambda}u'(d_1(a) - Z(X^B)) + (1 - \bar{\lambda})u'(d_2(a, b) - Z(X^B))} \frac{(V^B(a, b, X^B) - V^B(a^*))}{(V^A(a, b, X^A) - V^B(a^*))}. \quad (35)$$

In a similar way, the FOC for b differs from the one of a central authority with fiscal power. Every marginal utility is weighted by the other country's Nash factor. Due to differing FOC, the action \tilde{a} , \tilde{b} and the burden sharing rule in form of \tilde{X}^A, \tilde{X}^B will in general not coincide with the solution of the central authority with fiscal power. Whether countries are able to agree upon the efficient actions depends on the amount of redistribution that is required by the Nash bargaining solution. Redistribution is costly. Therefore, when countries move away from the solution of a central authority with fiscal power and choose $\tilde{X}^j \neq X^j$, the surplus from changing the actions shrinks with the redistribution.

7 Winners and losers from cooperation

In this section, we consider the different types of cooperation discussed so far with respect to gains and losses for individual countries and potential Pareto improvements compared to the non-cooperative outcome. Analyzing which countries in their role as crisis or affected country benefit from the different types of cooperation is important for understanding their incentives to agree on cooperation.

7.1 Central authority without fiscal power

The introduction of a central authority with mandating power only has an effect on the equilibrium if it mandates actions different from the ones taken in the non-cooperative game. As it has no fiscal power, which would allow for burden sharing, it cannot induce Pareto improvements:

Proposition 11 *Suppose no country is indifferent between a bail-out and no intervention. Then, a central authority with mandating power can only increase global welfare at the expense of the welfare of one country. It cannot induce a Pareto improvement.*

Proof.

Suppose there is no intervention by the governments or a bail-out of Bank B. Then, if the central

authority mandates $a' = (bo, n)$, Country A is made worse off as $V_{bo,n}^A < \max\{V_{n,bo}^A; V_{n,n}^A\}$.

Suppose there is no intervention by the governments. Then, if the central authority mandates $a' = (n, bo)$, Country B is made worse off as $V_{n,bo}^B < V_{n,n}^A$. ■

If, in the non-cooperative equilibrium, Country A does not choose to bail-out its bank, then if it is mandated to do so, given that there is no burden sharing, this can only deteriorate its domestic welfare. The other country benefits from this. It can also be optimal to have a bail-out of Bank B. If Country B is mandated to do a bail-out, although in the non-cooperative equilibrium it did not choose this option, then the decision of the central authority raises welfare of Country A at the expense of Country B.

7.2 Central authority with fiscal power

The decision of a central authority with fiscal power implies that the welfare of one country increases, while the other country can experience a gain or a loss in welfare. To shed some light on this, we discuss under which conditions Pareto improvements are possible.

To start with, we consider cases where the actions taken in the non-cooperative equilibrium coincide with the choice of the central authority. Then, the central authority only modifies the costs that each country has to bear together with b . In this case, no Pareto improvement is possible, which we have already proven as part of Proposition 10. If Country B does a bail-out and this is globally optimal, then burden sharing will lead to a nonnegative contribution of Country A, $X^A \geq 0$, which can benefit Country B but harm Country A. If instead the latter does a bail-out, the central authority will use this instrument to implement some consumption smoothing across countries. From Proposition 9, we know that the contribution of Country B will be greater than zero, $X^B > 0$. This increases welfare of Country A, but decreases welfare of Country B.

When the central planner does not only introduce burden-sharing, but also mandates actions different from the ones taken in the sequential game, this can, but does not need to imply improvements for both countries. There are three cases where the central authority with fiscal

power may coordinate on actions different from the ones taken in the sequential game:

- (i) $a^* = (n, n)$ and $a' = (n, bo)$,
- (ii) $a^* = (n, n)$ and $a' = (bo, n)$,
- (iii) $a^* = (n, bo)$ and $a' = (bo, n)$.

In all cases, welfare in Country B is strictly higher than in Country A. Furthermore, it can be shown that there is a strictly positive net gain for Country B due to the introduction of a central authority with fiscal power relative to the outcome of the sequential game for Cases (i) and (ii). This is because both countries would have the same utility in the non-cooperative game. For Case (iii), we find that each country can be a net winner or loser. As G^A might be larger than G^B , it is possible that $X^B > G^B$ and that Country B loses welfare. These results are derived in the Appendix.

7.3 Discussion

Table 3: Winners from cooperation

<i>Form of Cooperation</i>	<i>Number of Winners</i>
Central authority without fiscal power	1
Central authority with fiscal power	1-2
Contracts	2

Table 3 summarizes the findings of the previous sections regarding winners and losers from the different forms of cooperation. Contracts imply, by their very nature, that both countries benefit. In contrast, the introduction of a central authority with mandating power only always makes one country worse off compared to the non-cooperative outcome. A central authority with additional fiscal power may be able to bring welfare improvements for both countries at the same time, though this is not guaranteed. It can be efficient to make one country worse off.

Among the three cooperation regimes we look at, a central authority with fiscal power achieves the highest overall welfare, which is our benchmark for efficiency. A clear ranking between contracts and a central authority with mandating power only, with respect to efficiency,

is not possible. A central authority with mandating power cannot alleviate the inefficiency due to no burden sharing, but can fully internalize spillover effects. While contracts allow for some form of burden sharing, redistribution limits the overall gains that can be realized by contracts. Due to their limitations, neither contracts nor a central authority with mandating power guarantee the implementation of the efficient actions.

As mentioned, contracts correspond to a form of ex-post cooperation. Knowing their roles in the bail-out game, after the realization of the third state, governments negotiate. A central authority represents a form of ex-ante cooperation. The setup described in Table 2 identifies Country A as the crisis country and Country B as the affected country, which is a reduced formulation in order to highlight the mechanisms in our model. We can think of a fourth state that is the mirror image of the third state, where the roles of the countries are interchanged. In this symmetric world, each country can take the role of the crisis country or the affected country when crisis occurs. Cooperation ex-ante takes place under uncertainty about the role each country has in case of a crisis. In this light, the above considerations may shed some light on the desirability and the incentives of countries to agree ex-ante on a form of cooperation.

8 Ring-fencing

Another form of government intervention, which can be observed during banking crises, is the ring-fencing of assets, i.e. the freeze of foreign asset holdings in domestic banks. During the current crisis, the German government froze assets of Lehman in order for domestic depositors to be reimbursed. (See Claessens (2009).) Furthermore, in the context of the bankruptcy case of Barings, counterparties and customers faced constraints in accessing their funds during the resolution process. When the Bank for Credit and Commerce International (BCCI) was resolved, California and New York ring-fenced assets in order to secure a higher share of the liquidation value for local depositors. Ring-fencing applied to all assets up to the total value of liabilities towards local depositors. (See Herring (2005).)

In our model, we define ring-fencing as an asset freeze, that is foreign depositors (either a bank or private households) that would like to withdraw early are prevented from doing so. Governments observe the state of the world and decide on the form of intervention before any claims are paid. Furthermore, we assume that a country only does ring-fencing if this implies a strictly higher welfare than any alternative.

No cross-country deposits To start with, we consider the case with interbank deposits only. In this case, ring-fencing is equivalent to an interbank deposit freeze at date $t = 1$. We extend the bail-out game as illustrated in Figure 4 and introduce the additional form of intervention called *ring-fencing*. The figure is a reduced form of the game given the optimality of mutual

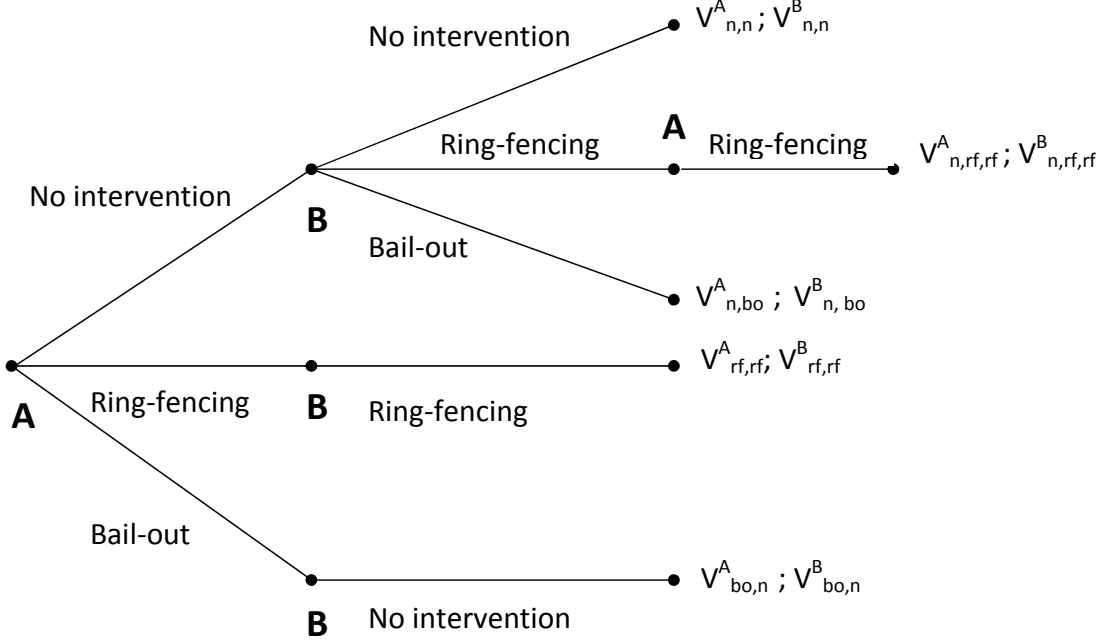


Figure 4: Intervention game in extensive form

ring-fencing. We show in the Appendix that the best response to ring-fencing is ring-fencing. Therefore, it does not matter for the pay-offs to depositors and thus the welfare levels of the countries which country chooses to ring-fence interbank deposits first. As interbank claims exactly offset each other, ring-fencing cannot prevent bankruptcy in Country A. Bank A has to be liquidated and the welfare level of Country A is the same as in the case where neither country intervenes:

$$V_{rf,rf}^A = V_{n,rf,rf}^A = u(\bar{q}). \quad (36)$$

In contrast, ring-fencing has a positive effect on the welfare level of Country B. Because interbank claims net out, contagion is avoided and welfare of Country B attains the first-best:

$$V_{rf,rf}^B = V_{n,rf,rf}^B = \bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(\bar{d}_2). \quad (37)$$

The following result on optimal strategies can be derived:

Proposition 12 *In the non-cooperative game without cross-country deposits, the crisis country never chooses to ring-fence assets although this could avoid contagion. Without any costs to ring-fencing, the affected country will always choose this option.*

Proof. See the Appendix. ■

As Country B always chooses to ring-fence foreign assets in order to avoid contagion, the number of SPNE reduces to the following two:

Proposition 13 (i) $a^* = (n, rf, rf)$ is a SPNE iff $V_{bo,n}^A \leq V_{n,rf,rf}^A$.

(ii) $a^* = (bo, n)$ is a SPNE iff $V_{bo,n}^A > V_{n,rf,rf}^A$.

Proof. Omitted. ■

We compare the SPNE of the game with the possible choices of a central authority with mandating power only:

Proposition 14 (i) *If the SPNE is $a^* = (bo, n)$, then this equilibrium coincides with the optimal solution of the central authority with mandating power a' .*

(ii) *If the SPNE is $a^* = (n, rf, rf)$, then $a' \in \{(n, rf, rf), (n, bo)\}$.*

Proof. See the Appendix. ■

As burden sharing makes bail-outs less costly, a central authority with fiscal power may find a bail-out of Bank A optimal. Therefore, in Case (ii) the set of possibly efficient actions given fiscal burden sharing changes to $a' \in \{(n, rf, rf), (n, bo), (bo, n)\}$. In the modified game, there is only scope for one specific type of contract as defined in Expression 34 because Country B always attains the maximum welfare level: $\tilde{a} = (n, bo)$ with $X^A = G^B(\bar{d}_2)$ and $X^B = 0$, i.e. Country A fully finances the bail-out of Bank B.

So far we have abstracted from any costs that ring-fencing might have. Yet, one can imagine that a country, which ring-fences assets, could be punished for its behavior, for example through the exclusion from the international interbank market in the future. Suppose the country that ring-fences suffers from a utility loss due to some penalty. Then ring-fencing may be no longer the dominant strategy of Country B. The severity of the punishment determines whether ring-fencing initiated by Country B is observed in equilibrium. Punishment could also be endogenous, giving an additional role to cooperation.

With cross-country deposits With cross-country deposits, the scope for ring-fencing increases. Countries can freeze interbank assets as well as private assets. The motivation of a government for ring-fencing becomes twofold. As before, freezing deposits prevents the withdrawal of assets, thereby eventually alleviating the liquidity problem at date $t = 1$ and preventing contagion. Moreover, by ring-fencing assets, a government can change the de-facto seniority of claims. It allows for a compensation of domestic depositors at the expense of foreigners. When a large fraction of assets deposited in the domestic bank is owned by foreigners, the incentives to ring-fence may therefore increase. It is crucial whether governments can discriminate between interbank and private deposits and freeze these assets independently of each other.

9 Conclusions

The financial system is more and more linked internationally. This has important implications for international crises and corresponding interventions by governments. We provide a model of contagion in an international setting with endogenous bail-out decisions. We study efficiency properties under different forms of cooperation in contrast to the non-cooperative outcome, identify winners and losers and point out factors that make cooperation more important.

Among the three different cooperation regimes we consider, a central authority with mandating and fiscal power achieves the highest overall welfare. A central authority with mandating power only can improve the global welfare as well, but to a lesser extent. Decisions by both types of central authority do not imply gains for both countries, i.e. Pareto improvements. While under contracts an agreement always implies a Pareto improvement, ex-post negotiations between governments can fall short on global efficiency both in terms of actions chosen and in terms of burden-sharing.

The model provides a framework to understand potential gains and losses for different countries from different cooperation regimes. In this regard, it can help guide current policy reforms like the one by the European Commission and provide some intuition for the negotiation processes. An important result of our analysis is that with equal country sizes larger cross-country deposit holdings improve the non-cooperative equilibrium. Therefore, cross-border deposit holdings by consumers can have positive effects by reducing externalities and free-riding problems. Another relevant aspect highlighted by our model is the case of asymmetric country sizes. The potential need for a bail-out at some point in time implies that it might be good to limit the

ratio of the financial sector of a country to its population, that is the tax base, when there is no ex-ante cooperation in crisis management.

The model may be a suitable framework to study other aspects of bail-outs. While we consider fiscal bail-outs, banks could also be saved through a bail-out financed by monetary policy where central banks are left to pick-up the bail-out bill. This would entail different trade-offs as e.g. the labor-leisure choice might be distorted by inflation.

Appendix A. Proofs

Proof of Proposition 3

Proof.

(i) $a^* = (bo, n)$ iff $V_{bo,n}^A > V_{n,bo}^A$ or $V_{n,bo}^B \leq V_{n,n}^B$ and $V_{bo,n}^A > V_{n,n}^A$.

If $V_{bo,n}^A > V_{n,bo}^A$, using $V_{bo,n}^B > V_{n,bo}^B \Rightarrow V_{bo,n}^A + V_{bo,n}^B > V_{n,bo}^A + V_{n,bo}^B$.

Using $V_{n,bo}^A > V_{n,n}^A$ and $V_{bo,n}^B > V_{n,n}^B \Rightarrow V_{bo,n}^A + V_{bo,n}^B > V_{n,n}^A + V_{n,n}^B$.

If $V_{bo,n}^A > V_{n,n}^A$ and $V_{n,n}^B \geq V_{n,bo}^B \Rightarrow V_{bo,n}^A + V_{n,n}^B > V_{n,n}^A + V_{n,bo}^B$.

Using $V_{bo,n}^B - V_{n,n}^B > V_{n,bo}^A - V_{n,n}^A \Rightarrow V_{bo,n}^A + V_{bo,n}^B > V_{n,bo}^A + V_{n,bo}^B$,

and as $V_{bo,n}^B > V_{n,n}^B \Rightarrow V_{bo,n}^A + V_{bo,n}^B > V_{n,n}^A + V_{n,n}^B$.

(ii) $a^* = (n, bo)$ iff $V_{n,bo}^B > V_{n,n}^B$ and $V_{bo,n}^A \leq V_{n,bo}^A$.

As $V_{n,bo}^A > V_{n,n}^A \Rightarrow V_{n,bo}^A + V_{n,bo}^B > V_{n,n}^A + V_{n,n}^B$.

(iii) $a^* = (n, n)$ iff $V_{n,bo}^B \leq V_{n,n}^B$ and $V_{bo,n}^A \leq V_{n,n}^A \Rightarrow V_{bo,n}^A \leq V_{n,n}^A < V_{n,bo}^A$,

and $V_{n,bo}^B \leq V_{n,n}^B < V_{bo,n}^B$,

which implies that in case (iii) no general statement can be made on actions maximizing global welfare. ■

Proof of Proposition 6

Proof. With constant country size implying $\bar{P} - \alpha = (1 - \beta)$, the first-order condition of Country A for b implies:

$$\frac{\alpha(\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(G(b))) + (\bar{P} - \alpha)[\bar{\lambda}u'(\bar{d}_1 - Z(G(b))) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G(b)))]}{\alpha(1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b)))} = \frac{1 - Z'(G(b))G'(b)}{Z'(G(b))G'(b)}.$$

The derivative of the left hand side (LHS) with respect to α , holding b constant, implies:

$$\begin{aligned}
& \frac{\partial LHS}{\alpha} \Big|_{b=\bar{b}} [\alpha(1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b)))]^2 \\
&= [(\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(G(b))) - \bar{\lambda}u'(\bar{d}_1 - Z(G(b))) - (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G(b)))] \\
&\alpha(1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b))) \\
&- [\alpha(\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(G(b))) + (\bar{P} - \alpha)[\bar{\lambda}u'(\bar{d}_1 - Z(G(b))) \\
&+ (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G(b)))](1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b))] \\
&= -[\bar{\lambda}u'(\bar{d}_1 - Z(G(b))) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G(b)))]\alpha(1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b))) \\
&- (\bar{P} - \alpha)[\bar{\lambda}u'(\bar{d}_1 - Z(G(b))) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G(b)))](1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b))) < 0.
\end{aligned}$$

The derivative of the LHS with respect to b implies:

$$\begin{aligned}
& \frac{\partial LHS}{b} (\alpha(1 - \bar{\lambda} - \epsilon)u'(b - Z(G(b))))^2 \\
&= -\alpha(\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(G(b))) + (\bar{P} - \alpha)[\bar{\lambda}u'(\bar{d}_1 - Z(G(b))) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G(b)))] \\
&\alpha(1 - \bar{\lambda} - \epsilon)u''(b - Z(G(b))) > 0.
\end{aligned}$$

The derivative of $Z'(G(b))G'(b)$ with respect to b is:

$$\frac{\partial Z'(G(b))G'(b)}{b} = Z''(G(b))(G'(b))^2 + Z'(G(b))G''(b) = Z''(G(b))(G'(b))^2 > 0.$$

Therefore, the derivative of the right hand side (RHS) with respect to b is negative. The statements on the derivatives above imply that an increase in α leads to a higher bailout level b being chosen by the government in Country A. The proof for Country B is analogous. ■

Proof of Proposition 7

Proof.

(i) Country B does a bail-out iff $V_{n,bo}^B > V_{n,n}^B$. Now:

$$\begin{aligned}
& \frac{\partial(V_{n,bo}^B - V_{n,n}^B)}{\partial(1 - \alpha)} \Big|_{b=\bar{b}} = u(\hat{q} - Z(G(b))) - [\bar{\lambda}u'(\bar{d}_1 - Z(G(b))) + (1 - \bar{\lambda})u'(b - Z(G(b)))] < 0 \\
&\Rightarrow \forall \alpha, \alpha' \in [0, 1] \text{ and } \forall b \in [\bar{d}_1, \bar{d}_2] : \alpha' > \alpha \Leftrightarrow V_{n,bo}^B(b; \alpha') > V_{n,bo}^B(b; \alpha).
\end{aligned}$$

Let $b = \arg \max V_{n,bo}^B(b; \alpha)$ and $b' = \arg \max V_{n,bo}^B(b; \alpha')$ with $\alpha' > \alpha$. Then, from optimal behavior of Country B and above: $V_{n,bo}^B(b'; \alpha') \geq V_{n,bo}^B(b; \alpha') > V_{n,bo}^B(b; \alpha)$.

(ii) Country A does a bail-out iff $V_{bo,n}^A > V_{n,n}^A$. Now:

$$\begin{aligned} \frac{\partial(V_{bo,n}^A - V_{n,n}^A)}{\partial(1-\beta)} \Big|_{b=\bar{b}} &= - [(\bar{\lambda} + \epsilon)u(\bar{d}_1 - Z^A(G^A(b))) + (1 - \bar{\lambda} - \epsilon)u(b - Z^A(G^A(b)))] \\ &+ [\bar{\lambda}u(\bar{d}_1 - Z^A(G^A(b))) + (1 - \bar{\lambda})u(\bar{d}_2 - Z^A(G^A(b)))] > 0 \\ \Rightarrow \forall \beta, \beta' \in [0, 1] \text{ and } \forall b \in [\bar{d}_1, \bar{d}_2] : \beta > \beta' &\Leftrightarrow V_{bo,n}^A(b; \beta') > V_{bo,n}^A(b; \beta). \end{aligned}$$

Let $b = \arg \max V_{bo,n}^A(b; \beta)$ and $b' = \arg \max V_{bo,n}^A(b; \beta')$ with $\beta > \beta'$. Then, from optimal behavior of Country A and above: $V_{bo,n}^A(b'; \beta') \geq V_{bo,n}^A(b; \beta') > V_{bo,n}^A(b; \beta)$. ■

Proof of Proposition 8

Proof.

(i) For Country A, we have:

$$Z^A(G) = \frac{\kappa\eta}{4} \left[1 - \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{G}{\alpha\kappa}} \right)^2 \right].$$

Holding b constant, we have:

$$\frac{\partial Z^A}{\partial \alpha} \Big|_{b=\bar{b}} = -\frac{G\eta}{4\alpha^2} \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{G}{\alpha\kappa}} \right) \left(\frac{1}{4} - \frac{G}{\alpha\kappa} \right)^{-\frac{1}{2}} < 0.$$

Country A does a bail-out if:

$$\frac{V_{bo,n}^A}{V_{n,n}^A} = \frac{(2\bar{\lambda} + \epsilon)u(\bar{d}_1 - Z(G^A(b))) + (1 - \bar{\lambda} - \epsilon)u(b - Z(G^A(b))) + (1 - \bar{\lambda})u(\bar{d}_2 - Z(G^A(b)))}{2u(\bar{q})} > 1$$

and

$$\frac{V_{bo,n}^A}{V_{n,bo}^A} = \frac{(2\bar{\lambda} + \epsilon)u(\bar{d}_1 - Z(G^A(b))) + (1 - \bar{\lambda} - \epsilon)u(b - Z(G^A(b))) + (1 - \bar{\lambda})u(\bar{d}_2 - Z(G^A(b)))}{u(\hat{q}) + \bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(b)} > 1.$$

Now:

$$\begin{aligned} & \frac{\partial(V_{bo,n}^A/V_{n,n}^A)}{\partial Z} \Big|_{b=\bar{b}} \\ &= - \frac{(2\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(G^A(b))) + (1 - \bar{\lambda} - \epsilon)u'(b - Z(G^A(b))) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G^A(b)))}{2u(\bar{q})} < 0 \\ &\Rightarrow \frac{\partial(V_{bo,n}^A/V_{n,n}^A)}{\partial \alpha} \Big|_{b=\bar{b}} > 0, \end{aligned}$$

and

$$\begin{aligned} & \frac{\partial(V_{bo,n}^A/V_{n,bo}^A)}{\partial Z} \Big|_{b=\bar{b}} \\ &= - \frac{(2\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(G^A(b))) + (1 - \bar{\lambda} - \epsilon)u'(b - Z(G^A(b))) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(G^A(b)))}{u(\hat{q}) + \bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(b)} < 0. \\ &\Rightarrow \frac{\partial(V_{bo,n}^A/V_{n,bo}^A)}{\partial \alpha} \Big|_{b=\bar{b}} > 0. \end{aligned}$$

(ii) For Country B, we have:

$$Z^B(G) = \frac{\kappa\eta}{4} \left[1 - \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{G}{\beta\kappa}} \right)^2 \right].$$

Holding b constant, we have:

$$\frac{\partial Z^B}{\partial \beta} \Big|_{b=\bar{b}} = - \frac{G\eta}{4\beta^2} \left(\frac{1}{2} + \sqrt{\frac{1}{4} - \frac{G}{\beta\kappa}} \right) \left(\frac{1}{4} - \frac{G}{\beta\kappa} \right)^{-\frac{1}{2}} < 0.$$

Country B does a bail-out if:

$$\frac{V_{n,bo}^B}{V_{n,n}^B} = \frac{u(\hat{q} - Z(G^B(b))) + \bar{\lambda}u(\bar{d}_1 - Z(G^B(b))) + (1 - \bar{\lambda})u(b - Z(G^B(b)))}{2u(\bar{q})} > 1.$$

Now:

$$\begin{aligned} & \frac{\partial(V_{n,bo}^B/V_{n,n}^B)}{\partial Z} \Big|_{b=\bar{b}} \\ &= - \frac{u'(\hat{q} - Z(G^B(b))) + \bar{\lambda}u'(\bar{d}_1 - Z(G^B(b))) + (1 - \bar{\lambda})u'(b - Z(G^B(b)))}{2u(\bar{q})} < 0 \\ &\Rightarrow \frac{\partial(V_{n,bo}^B/V_{n,n}^B)}{\partial \beta} \Big|_{b=\bar{b}} > 0. \end{aligned}$$

■

Proof of Proposition 9

Proof.

(1) Interior solution, where Condition 33 holds. For the case (n,bo), we have:

$$1 = \frac{\bar{\lambda}u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda})u'(b - Z(X^B))}{u'(\hat{q} - Z(X^A))} \frac{Z'(X^B)}{Z'(X^A)}.$$

Suppose that $X^A \geq X^B$. Then:

$$\begin{aligned} \bar{\lambda}u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda})u'(b - Z(X^B)) &\geq u'(\hat{q} - Z(X^A)) \\ \Rightarrow u'(\bar{d}_1 - Z(X^B)) &\geq u'(\hat{q} - Z(X^A)) \\ \Rightarrow Z(X^B) - Z(X^A) &\geq \bar{d}_1 - \hat{q} > 0 \\ \Rightarrow X^B &> X^A, \end{aligned}$$

which is a contradiction. Therefore, $X^B > X^A$.

For the case (bo,n), we have:

$$1 = \frac{\bar{\lambda}u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(X^B))}{(\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(X^A)) + (1 - \bar{\lambda} - \epsilon)u'(b - Z(X^A))} \frac{Z'(X^B)}{Z'(X^A)}.$$

Suppose that $X^A \geq X^B$. Then, given $b \in [\bar{d}_1, \bar{d}_2]$:

$$\begin{aligned} \lambda u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(X^B)) &\geq (\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(X^A)) + (1 - \bar{\lambda} - \epsilon)u'(b - Z(X^A)) \\ \Rightarrow \lambda u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda})u'(\bar{d}_2 - Z(X^B)) &\geq (\bar{\lambda} + \epsilon)u'(\bar{d}_1 - Z(X^A)) + (1 - \bar{\lambda} - \epsilon)u'(\bar{d}_2 - Z(X^A)) \\ \Rightarrow \bar{\lambda}[u'(\bar{d}_1 - Z(X^B)) - u'(\bar{d}_1 - Z(X^A))] + (1 - \bar{\lambda})[u'(\bar{d}_2 - Z(X^B)) - u'(\bar{d}_2 - Z(X^A))] & \\ \geq \epsilon[u'(\bar{d}_1 - Z(X^A)) - u'(\bar{d}_2 - Z(X^A))] &> 0 \\ \Rightarrow Z(X^B) > Z(X^A) \Rightarrow X^B > X^A, & \end{aligned}$$

which is a contradiction. Therefore, $X^B > X^A$.

(2) Corner solutions. Condition 33 might not bind as contributions by countries are bounded from below, i.e. $X^A, X^B \geq 0$. There are two possible corner solutions in which this could be

the case:

- (i) $X^B = 0$ and $X^A = G$,
- (ii) $X^A = 0$ and $X^B = G$.

We now show that only case (ii) can be chosen optimally by a central authority, which implies that in any corner solution $X^B > X^A$.

Suppose (i), i.e. $X^B = 0$ and $X^A = G$. Then, the FOC of the central authority with respect to X^A becomes:

$$\begin{aligned} \frac{\partial V}{\partial X^A} = & -[(\bar{\lambda} + \epsilon)u'(d_1^A(a) - Z(G)) + (1 - \bar{\lambda} - \epsilon)u'(d_2^A(a, b) - Z(G))]Z'(G) \\ & + [\bar{\lambda}u'(d_1^B(a)) + (1 - \bar{\lambda})u'(d_2^B(a, b))]Z'(0). \end{aligned}$$

This can be rearranged to:

$$\begin{aligned} \frac{\partial V}{\partial X^A} = & \bar{\lambda}[u'(d_1^B(a))Z'(0) - u'(d_1^A(a) - Z(G))Z'(G)] \\ & + (1 - \bar{\lambda} - \epsilon)[u'(d_2^B(a, b))Z'(0) - u'(d_2^A(a, b) - Z(G))Z'(G)] \\ & + \epsilon[u'(d_2^B(a, b))Z'(0) - u'(d_1^A(a) - Z(G))Z'(G)] < 0, \end{aligned}$$

as $u()$ is concave, $Z()$ is convex, $d_2^B \geq d_2^A \geq d_1^A$ and $d_1^B \geq d_1^A$. Welfare could be improved by decreasing X_A and increasing X_B . Therefore, $X_A = G$ cannot be the optimal solution chosen by a central authority. ■

Proof of Proposition 10

Proof.

(1) A contract (\tilde{a}, \tilde{X}^A) must imply a Pareto improvement as otherwise the participation constraint of one country would be violated.

(2) A change in actions alone (excluding the case of Country A or Country B being indifferent between a bail-out and another action) cannot induce a Pareto improvement. Suppose there is no intervention by the governments or a bail-out of Bank B, i.e. $a^* \in \{(n, n), (n, bo)\}$. Then, if the central authority mandates (bo, n) , Country A is made worse off as $V_{bo, n}^A < \max\{V_{n, bo}^A; V_{n, n}^A\}$. Suppose there is no intervention by the governments, that is $a^* = (n, n)$. Then, if the central

authority mandates (n, bo) , Country B is made worse off as $V_{n,bo}^B < V_{n,n}^A$.

(3) A change in the contribution levels without a change of actions cannot bring a Pareto improvement. Suppose $\tilde{a} = a^*$. Then, any change in the contribution levels makes one country better off and one country worse off as at an optimum $G(a, b) = X^A + X^B$ binds.

(4) A change in the degree of the bail-out cannot induce a Pareto improvement as the degree of the bail-out b does not affect the welfare of the country that does not conduct the bail-out.

(5) a^* can only be inefficient if $a^* \in \{(n, bo), (n, n)\}$ (see Proposition 3). Furthermore, it follows that if $a^* = (n, bo)$, then $\tilde{a} \in \{(bo, n)\}$ and if $a^* = (n, n)$, then $\tilde{a} \in \{(bo, n), (n, bo)\}$.

(6) If a country did not do a bail-out before, and agrees in the contract to do so, then it has to receive a positive payment. This is the case as the country weakly preferred not to do a bail-out and as the gains from the change of action are shared. ■

Proof of Proposition 12

Proof. We consider the two cases where (1) Country A ring-fences first, and (2) Country B ring-fences first. We solve each case by backward induction.

(1) Given ring-fencing by Country A, the welfare levels of Country B for the different responses (no intervention, bail-out, ring-fencing) are as follows:

$$V_{rf,n}^B = u(q_r), \text{ with } q_r = \frac{(1-y)r + y}{1+z} < \bar{q},$$

$$V_{rf,bo}^B = \bar{\lambda}u(\bar{d}_1 - G(b)) + (1 - \bar{\lambda})u(b - G(b)), \text{ with } G(b) = z\bar{d}_1 - r \left((1-y) - \frac{(1-\bar{\lambda})b}{R} \right),$$

$$V_{rf,rf}^B = \bar{\lambda}u(\bar{d}_1) + (1 - \bar{\lambda})u(\bar{d}_2).$$

It follows from this that the best response of Country B to ring-fencing by Country A is ring-fencing. The welfare level for Country A, if it ring-fences first, is:

$$V_{rf,rf}^A = u(\bar{q}).$$

Comparing this with Equations 19, 20 and 22, it can be seen that Country A never chooses to ring-fence first.

(2) Given ring-fencing by Country B, the welfare levels of Country A for the different responses

(no intervention, ring-fencing) are:

$$V_{n,rf,n}^A = u(q_r), \text{ with } q_r = \frac{(1-y)r+y}{1+z} < \bar{q},$$

$$V_{n,rf,rf}^A = u(\bar{q}).$$

Note that a bail-out by Country A will not be chosen in the third round. If Country A prefers that option, it does already choose it in the first round. Therefore, given that Country B ring-fences, a bail-out cannot be optimally chosen by Country A. The best response of Country A to ring-fencing by Country B is ring-fencing. The welfare level of Country B, if it ring-fences first, is:

$$V_{n,rf,rf}^B = \bar{\lambda}u(\bar{d}_1) + (1-\bar{\lambda})u(\bar{d}_2),$$

which is strictly higher than all other welfare levels except for the case where Country A does a bail-out. Therefore, if Country A does not do a bail-out, Country B always ring-fences. ■

Proof of Proposition 14

Proof.

(i) $a^* = (bo, n) \Rightarrow V_{bo,n}^A > V_{n,rf,rf}^A$. Therefore, together with $V_{bo,n}^B = V_{n,rf,rf}^B$, we have $V_{bo,n}^A + V_{bo,n}^B > V_{n,rf,rf}^A + V_{n,rf,rf}^B$.

(ii) $a^* = (n, rf, rf) \Rightarrow V_{bo,n}^A \leq V_{n,rf,rf}^A \Rightarrow V_{bo,n}^A + V_{bo,n}^B \leq V_{n,rf,rf}^A + V_{n,rf,rf}^B$.

A clear ranking in terms of welfare between (n, bo) and (n, rf, rf) is not possible because $V_{n,bo}^A > V_{n,rf,rf}^A$, but $V_{n,rf,rf}^B < V_{n,bo}^B$. ■

Appendix B. Lump-sum taxation

With lump-sum taxation, Country A always prefers (bo, n) over (n, n) , as long as $\bar{\lambda} < 1$. Due to the free-riding problem, no clear statement can be made on (bo, n) vs. (n, bo) .

Proof.

$$\begin{aligned}
V_{bo,n}^A &> V_{n,n}^A \\
&\Leftrightarrow (\bar{\lambda} + \epsilon)u(\bar{d}_1 - \epsilon\bar{d}_1) + (1 - \bar{\lambda})u(\bar{d}_2 - \epsilon\bar{d}_1) > u(\bar{q}) \\
&\Rightarrow u(\bar{d}_1 - \epsilon\bar{d}_1) > u(\bar{q}) \\
&\Leftrightarrow \bar{d}_1 - \epsilon\bar{d}_1 > \bar{q} \\
&\Leftrightarrow \bar{d}_1 = \frac{y}{\bar{\lambda}} > \frac{y + (1 - y)r}{1 - \epsilon} = \frac{\bar{q}}{1 - \epsilon}.
\end{aligned}$$

Using $\epsilon \leq 1 - \bar{\lambda}$ implies

$$\Rightarrow \frac{y}{\bar{\lambda}} > \frac{y + (1 - y)r}{\bar{\lambda}}.$$

This is true as $\bar{\lambda} < 1 \Rightarrow y < 1$.

■

With lump-sum taxation, Country B always does a bail-out. In the following we prove that a full bail-out implies a higher welfare in Country B than no intervention.

Proof.

$$\begin{aligned}
V_{n,bo}^B &> V_{n,n}^B \\
&\Leftrightarrow \bar{\lambda}u(\bar{d}_1 - z(\bar{d}_1 - \hat{q})) + (1 - \bar{\lambda})u(\bar{d}_2 - z(\bar{d}_1 - \hat{q})) > u(\bar{q}) \\
&\Rightarrow u(\bar{d}_1 - z(\bar{d}_1 - \hat{q})) > u(\bar{q}) \\
&\Leftrightarrow \bar{d}_1 - z(\bar{d}_1 - \hat{q}) > \bar{q} \\
&\Leftrightarrow \bar{d}_1(1 - z) + z\frac{\bar{q} + z\bar{d}_1}{1 + z} - \bar{q} > 0 \\
&\Leftrightarrow \bar{d}_1(1 - z) + \frac{z^2\bar{d}_1 - \bar{q}}{1 + z} > 0 \\
&\Leftrightarrow \bar{d}_1 - \bar{q} > 0.
\end{aligned}$$

■

Appendix C. First-order conditions of the central authority with fiscal power

Suppose the central authority implements a bail-out of Bank A, then it faces the following FOCs:

$$\begin{aligned} \frac{\partial V}{\partial b} \Big|_{a=(bo,n)} &= \Theta^A (1 - \bar{\lambda} - \epsilon) u'(b - Z(X^A)) \\ &- \Theta^B [\bar{\lambda} u'(\bar{d}_1 - Z(G^A(b) - X^A)) + (1 - \bar{\lambda}) u'(\bar{d}_2 - Z(G^A(b) - X^A))] Z'(G^A(b) - X^A) G^{A'}, \end{aligned}$$

and

$$\begin{aligned} \frac{\partial V}{\partial X^A} \Big|_{a=(bo,n)} &= -\Theta^A [(\bar{\lambda} + \epsilon) u'(\bar{d}_1 - Z(X^A)) + (1 - \bar{\lambda} - \epsilon) u'(b - Z(X^A))] Z'(X^A) \\ &+ \Theta^B [\bar{\lambda} u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda}) u'(\bar{d}_2 - Z(X^B))] Z'(X^B). \end{aligned}$$

Suppose the central authority implements a bail-out of Bank B, then it faces the following FOCs:

$$\begin{aligned} \frac{\partial V}{\partial b} \Big|_{a=(n,bo)} &= -\Theta^B G^{B'} \\ &[\bar{\lambda} u'(\bar{d}_1 - Z(G^B(b) - X^A)) Z'(G^B(b) - X^A) + (1 - \bar{\lambda}) u'(b - Z(G^B(b) - X^A)) (Z'(G^B(b) - X^A) - 1)], \end{aligned}$$

and

$$\frac{\partial V}{\partial X^A} \Big|_{a=(n,bo)} = -\Theta^A u'(\hat{q} - Z(X^A)) Z'(X^A) + \Theta^B [\bar{\lambda} u'(\bar{d}_1 - Z(X^B)) + (1 - \bar{\lambda}) u'(b - Z(X^B))] Z'(X^B).$$

Appendix D. The bail-out game with simultaneous moves

Note that the following three inequalities hold:

$$\begin{aligned} V_{n,bo}^A &> V_{n,n}^A, \\ V_{bo,n}^B &> V_{n,n}^B, \\ V_{bo,n}^B &> V_{n,bo}^B. \end{aligned}$$

Therefore, all possible welfare orderings for Country A are:

$$(A-i) V_{bo,n}^A > V_{n,n}^A \text{ and } V_{bo,n}^A > V_{n,bo}^A,$$

$$(A-ii) V_{bo,n}^A > V_{n,n}^A \text{ and } V_{bo,n}^A \leq V_{n,bo}^A,$$

$$(A-iii) V_{bo,n}^A \leq V_{n,n}^A.$$

For Country B all possible welfare orderings are:

$$(B-i) V_{n,bo}^B > V_{n,n}^B,$$

$$(B-ii) V_{n,bo}^B \leq V_{n,n}^B.$$

Combining the two countries, there are in total 6 different orderings possible. The following proposition reports all equilibria for all cases:

Proposition 15 *(i) Suppose (A-i) and (B-i) hold, then the game has one Nash equilibrium $a^* = (bo, n)$.*

(ii) Suppose (A-i) and (B-ii) hold, then the game has one Nash equilibrium $a^ = (bo, n)$.*

(iii) Suppose (A-ii) and (B-i) hold, then the game has two Nash equilibria $a_1^ = (bo, n)$ and $a_2^* = (n, bo)$.*

(iv) Suppose (A-ii) and (B-ii) hold, then the game has one Nash equilibrium $a^ = (bo, n)$.*

(v) Suppose (A-iii) and (B-i) hold, then the game has one Nash equilibrium $a^ = (n, bo)$. (vi) Suppose (A-iii) and (B-ii) hold, then the game has one Nash equilibrium $a^* = (n, n)$.*

Note that in case (iii) there are two Nash equilibria. While in this case $V_{n,n}$ is always smaller than $V_{n,bo}$, there is no clear ordering between $V_{bo,n}$ and $V_{n,bo}$. Both (bo, n) and (n, bo) are equilibria of the simultaneous game and can, depending on parameters, be efficient. Thus, in the simultaneous game, coordination failure can occur. This is the main difference to the sequential game where instead a free-riding problem arises.

Appendix E. Unilateral commitment

Suppose a country can commit to an action. From the structure of the sequential game it is obvious that only commitment of the second mover is relevant. Commitment of Country B can tackle the potential inefficiency due to free-riding by Country A. In a situation described by (ii)

in Proposition 2 commitment can change the equilibrium outcome. If Country B commits not to intervene, then the subgame-perfect Nash equilibrium is $a^* = (bo, n)$. As $V_{bo,n}^B > V_{n,bo}^B$, Country B benefits from the possibility to commit, while Country A loses as $V_{bo,n}^A < V_{n,bo}^A$. The same considerations apply to the case with cross-country deposits. With cross-country deposits, it may also be sufficient for removing the free-riding problem that Country B commits to a degree of bail-out $b < b^*$ in order to induce the equilibrium $a^* = (bo, n)$. A lower b decreases the welfare level of Country A given a bail-out in Country B just as the commitment to no intervention does.

Appendix F. Winners and losers under a central authority with fiscal power

There are three possible cases in which a central authority with fiscal power chooses a set of actions different to the outcome of the sequential game. These are:

- (i) $a^* = (n, n)$ and $a' = (n, bo)$,
- (ii) $a^* = (n, n)$ and $a' = (bo, n)$,
- (iii) $a^* = (n, bo)$ and $a' = (bo, n)$.

In the following we study for each of these cases, which of the two countries wins and loses due to the presence of a central authority with fiscal power. The results are derived assuming symmetric welfare weights, i.e. $\Theta^A = \Theta^B$.

(i) $a^* = (n, n)$ and $a' = (n, bo)$. We show that in this case, under a central authority with fiscal power, welfare in Country B is strictly higher than in Country A, i.e. $V_{n,bo}^B > V_{n,bo}^A$. In Proposition 9, we showed that $X^B > X^A$.

Therefore:

$$\frac{u'(\hat{q} - Z(X^A))}{\bar{\lambda}u'(\bar{d}_1 - Z(G^B(b) - X^A)) + (1 - \bar{\lambda})u'(b - Z(G^B(b) - X^A))} = \frac{Z'(X^B)}{Z'(X^A)} > 1$$

$$\Leftrightarrow \bar{\lambda}u'(\bar{d}_1 - Z(G^B(b) - X^A)) + (1 - \bar{\lambda})u'(b - Z(G^B(b) - X^A)) < u'(\hat{q} - Z(X^A)).$$

Due to concavity of $u'()$, it follows that:

$$\begin{aligned} \bar{\lambda}u(\bar{d}_1 - Z(G^B(b) - X^A)) + (1 - \bar{\lambda})u(b - Z(G^B(b) - X^A)) &> u(\hat{q} - Z(X^A)) \\ \Leftrightarrow V_{n,bo}^B &> V_{n,bo}^A. \end{aligned}$$

As both countries would have the same welfare level in the sequential game, that is $V_{n,n}^A = V_{n,n}^B = u(\bar{q})$, this implies that the net gain of Country B from the presence of a central authority with fiscal power is also larger than that of Country A. Note that while the former is strictly positive, it is possible for the latter to be negative.

(ii) $a^* = (n, n)$ and $a' = (bo, n)$. We show that in this case, under a central authority with fiscal power, welfare in Country B is strictly higher than in Country A, i.e. $V_{bo,n}^B > V_{bo,n}^A$. In Proposition 9, we showed that $X^B > X^A \forall b \in [\bar{d}_1, \bar{d}_2]$. Therefore:

$$\begin{aligned} \frac{u'(\bar{d}_1 - Z(X^A))}{u'(\bar{d}_1 - Z(G^B(b) - X^A))} &> 1 \\ \Leftrightarrow u'(\bar{d}_1 - Z(G^B(b) - X^A)) &< u'(\bar{d}_1 - Z(X^A)) \\ \Leftrightarrow u(\bar{d}_1 - Z(G^B(b) - X^A)) &> u(\bar{d}_1 - Z(X^A)) \\ \Leftrightarrow V_{bo,n}^B &> V_{bo,n}^A. \end{aligned}$$

Again, as welfare in the two countries in the sequential game is equal, this implies that Country B enjoys a larger and strictly positive net gain. Country A can gain or loose due to the presence of a central authority.

(iii) $a^* = (n, bo)$ and $a' = (bo, n)$. The proof on the welfare ordering under $a' = (bo, n)$ from (ii) remains valid. Therefore, welfare in Country B is strictly larger than welfare in Country A. In this case though, no clear statement can be made on who enjoys higher net gains relative to the sequential game, as G^A might be larger than G^B , and therefore it is possible that $X^B > G^B$. Thus, each country might gain or loose due to the presence of a central authority with fiscal power.

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